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ABSTRACT

Developed as part of the Marine Corps Institute (MCI) correspondence training program, this course on antenna construction and propagation of radio waves is designed to provide communicators with instructions in the selection and/or construction of the proper antenna(s) for use with current field radio equipment. Introductory materials include specific information for MCI students, a course introduction, and a study guide (guidelines to complete the course). The 11-hour course contains four study units. Each study unit begins with a general objective. The study units are divided into numbered work units, each presenting one or more specific objectives. Contents of a work unit include a text and study questions/exercises. Answer keys are found at the end of each study unit. At the end of the course is a review lesson. Topics covered in the study units include radio communications, propagation of radio waves, antennas, and site selection and antenna grounding. Appendixes include discussions of field expedient construction and Electromagnetic Compatibility Analysis Center capabilities and services. (YLB)

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25.15g
6 Dec 1994

1. ORIGIN

MCI course 25.15g, Antenna Construction and Propagation of Radio Waves, has been prepared by the Marine Corps Institute.

2. APPLICABILITY

This course is for instructional purposes only.

JMD Holladay
J. M. D. HOLLADAY
Lieutenant Colonel, U. S. Marine Corps
Deputy Director

ACKNOWLEDGMENT

The Marine Corps Institute, Marine Barracks, Washington, D.C. gratefully acknowledges the important contributions provided by the following MCI personnel in developing and publishing the revision of this course:

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The Marine Corps Institute gratefully acknowledges the assistance of Senior Schools, Marine Corps Communications-Electronics School, Marine Corps Air-Ground Combat Center, 29 Palms, Ca. in the formal review of this course.

INFORMATION

FOR

MCI STUDENTS

Welcome to the Marine Corps Institute training program. Your interest in self-improvement and increased professional competence is commendable.

Information is provided below to assist you in completing the course. Please read this guidance before proceeding with your studies.

1. MATERIALS

Check your course materials. You should have all the materials listed in the "Course Introduction." In addition you should have an envelope to mail your review lesson back to MCI for grading unless your review lesson answer sheet is of the self-mailing type. If your answer sheet is the pre-printed type, check to see that your name, rank, and social security number are correct. Check closely, your MCI records are kept on a computer and any discrepancy in the above information may cause your subsequent activity to go unrecorded. You may correct the information directly on the answer sheet. If you did not receive all your materials, notify your training NCO. If you are not attached to a Marine Corps unit, request them through the Hotline (autovon 288-4175 or commercial 202-433-4175).

2. LESSON SUBMISSION

The self-graded exercises contained in your course are not to be returned to MCI. Only the completed review lesson answer sheet should be mailed to MCI. The answer sheet is to be completed and mailed only after you have finished all of the study units in the course booklet. The review lesson has been designed to prepare you for the final examination.

It is important that you provide the required information at the bottom of your review lesson answer sheet if it does not have your name and address printed on it. In courses in which the work is submitted on blank paper or printed forms, identify each sheet in the following manner:

DOE, John J. Sgt 332-11-9999
08.4g, Forward Observation
Review Lesson
Military or office address
(RUC number, if available)

Submit your review lesson on the answer sheet and/or forms provided. Complete all blocks and follow the directions on the answer sheet for mailing. Otherwise, your answer sheet may be delayed or lost. If you have to interrupt your studies for any reason and find that you cannot complete your course in one year, you may request a single six month extension by contacting your training NCO, at least one month prior to your course completion deadline date. If you are not attached to a Marine Corps unit you may make this request by letter. Your commanding officer is notified monthly of your status through the monthly Unit Activity Report. In the event of difficulty, contact your training NCO or MCI immediately.

3. MAIL-TIME DELAY

Presented below are the mail-time delays that you may experience between the mailing of your review lesson and its return to you.

	TURNAROUND MAIL TIME	MCI PROCESSING TIME	TOTAL NUMBER DAYS
EAST COAST	16	5	21
WEST COAST	16	5	21
FPO NEW YORK	18	5	23
FPO SAN FRANCISCO	22	5	27

You may also experience a short delay in receiving your final examination due to administrative screening required at MCI.

4. GRADING SYSTEM

LESSONS			EXAMS	
GRADE	PERCENT	MEANING	GRADE	PERCENT
A	94-100	EXCELLENT	A	94-100
B	86-93	ABOVE AVERAGE	B	86-93
C	78-85	AVERAGE	C	78-85
D	70-77	BELOW AVERAGE	D	65-77
NL	BELOW 70	FAILING	F	BELOW 65

You will receive a percentage grade for your review lesson and for the final examination. A review lesson which receives a score below 70 is given a grade of NL (no lesson). It must be resubmitted and PASSED before you will receive an examination. The grade attained on the final exam is your course grade, unless you fail your first exam. Those who fail their first exam will be sent an alternate exam in which the highest grade possible is 65%. Failure of the alternate will result in failure of the course.

5. FINAL EXAMINATION

ACTIVE DUTY PERSONNEL: When you pass your REVIEW LESSON, your examination will be mailed automatically to your commanding officer. The administration of MCI final examinations must be supervised by a commissioned or warrant officer or a staff NCO.

OTHER PERSONNEL: Your examination may be administered and supervised by your supervisor.

6. COMPLETION CERTIFICATE

The completion certificate will be mailed to your commanding officer and your official records will be updated automatically. For non Marines, your completion certificate is mailed to your supervisor.

7. RESERVE RETIREMENT CREDITS

Reserve retirement credits are awarded to inactive duty personnel only. Credits awarded for each course are listed in the "Course Introduction." Credits are only awarded upon successful completion of the course. Reserve retirement credits are not awarded for MCI study performed during drill periods if credits are also awarded for drill attendance.

8. DISENROLLMENT

Only your commanding officer can request your disenrollment from an MCI course. However, an automatic disenrollment occurs if the course is not completed (including the final exam) by the time you reach the CCD (course completion deadline) or the ACCD (adjusted course completion deadline) date. This action will adversely affect the unit's completion rate.

9. ASSISTANCE

Consult your training NCO if you have questions concerning course content. Should he/she be unable to assist you, MCI is ready to help you whenever you need it. Please use the Student Course Content Assistance Request Form (ISD-1) attached to the end of your course booklet or call one of the AUTOVON telephone numbers listed below for the appropriate course writer section.

PERSONNEL/ADMINISTRATION	288-3259
COMMUNICATIONS/ELECTRONICS/AVIATION NBC/INTELLIGENCE	288-3604
INFANTRY	288-3611
ENGINEER/MOTOR TRANSPORT	288-2275
SUPPLY/FOOD SERVICES/FISCAL	288-2285
TANKS/ARTILLERY/INFANTRY WEAPONS REPAIR LOGISTICS/EMBARKATION/MAINTENANCE MANAGEMENT/ ASSAULT AMPHIBIAN VEHICLES	288-2290

For administrative problems use the UAR or call the MCI HOTLINE: 288-4175.

For commercial phone lines, use area code 202 and prefix [illegible]3 instead of 288.

PREFACE

ANTENNA CONSTRUCTION AND PROPAGATION OF RADIO WAVES has been designed to provide privates through gunnery sergeants in occupational fields 25 and 28; a source of study on the propagation of radio waves and the construction and repair of conventional and field expedient antennas.

SOURCE MATERIALS

FM 24-18	Field Radio Techniques, July 1965
TM-06728A-15	Antenna System AS-2236/GRC, September 1968
TM-07505A-14	Antenna AS-2851/TR, August 1972
TM-07508A-14	Antenna AS-2259/GR, May 1974
TM-11-5820-348-15	Antenna Equipment RC-292, May 1966
TM-11-666	Antennas and Radio Propagation, February 1953
COS-0733-B10, COS-9328-A10	Conventional and Field Expedient Antennas, 1981
HO.9 HR.14	Field Expedient Antennas and Radio Wave Propagation
OH 10-3	Radio Operator's Handbook, Sep 1980
ECAC-CR-81-019	Operational Support to the U. S. Marine Corps, Feb 1981

ANTENNA CONSTRUCTION AND PROPAGATION OF RADIO WAVES

Course Introduction

ANTENNA CONSTRUCTION AND PROPAGATION OF RADIO WAVES is designed to provide communicators with instructions in the selection and/or construction of the proper antenna(s) for use with current field radio equipment.

ADMINISTRATIVE INFORMATION

ORDER OF STUDIES

Study Unit Number	Study Hours	Subject Matter
1	1	Radio Communications
2	2	Propagation of Radio Waves
3	3	Antennas
4	1	Site Selection and Antenna Grounding
Appendix I		Field Expedient Construction. NOTE: Required reading for study unit #3.
Appendix II		Electromagnetic Compatbility analysis center (ECAC) capabilities and services
	2	REVIEW LESSON
	2	FINAL EXAMINATION
	11	

RESERVE RETIREMENT CREDITS: 3

EXAMINATION: Supervised final examination without textbook or notes with a time limit of 2 hours.

MATERIALS: MCI 25.15, Antenna Construction and Propagation of Radio Waves. Review lesson and answer sheet.

RETURN OF MATERIALS: Students who successfully complete this course are permitted to keep the course materials.

Students disenrolled for inactivity or at the request of their commanding officer will return all course materials.

HOW TO TAKE THIS COURSE

This course contains 4 study units. Each study unit begins with a general objective which is a statement of what you should learn from that study unit. The study units are divided into numbered work units, each presenting one or more specific objectives. Read the objective(s) and then the work unit text. At the end of the work unit text are study questions which you should be able to answer without referring to the text of the work unit. After answering the questions, check you answers against the correct ones listed at the end of the study unit. If you miss any of the questions, you should restudy the text of the work unit until you understand the correct response. When you have mastered one study unit, move on to the next. After you have completed all study units, complete the review lesson and take it to your training officer or NCO for mailing to MCI. MCI will mail the final examination to your training officer or NCO when you pass the review lesson.

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MARINE CORPS INSTITUTE

STUDY GUIDE

Welcome to the Marine Corps Institute correspondence training program. By enrolling in this course, you have shown a desire to improve the skills you need for effective job performance, and MCI has provided materials to help you achieve your goal. Now all you need is to develop your own method for using these materials to best advantage.

The following guidelines present a four-part approach to completing your MCI course successfully:

1. Make a "reconnaissance" of your materials;
2. Plan your study time and choose a good study environment;
3. Study thoroughly and systematically;
4. Prepare for the final exam.

I. MAKE A "RECONNAISSANCE" OF YOUR MATERIALS

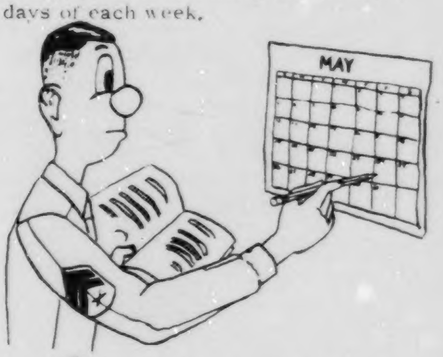
Begin with a look at the course introduction page. Read the COURSE INTRODUCTION to get the "big picture" of the course. Then read the MATERIALS section near the bottom of the page to find out which text(s) and study aids you should have received with the course. If any of the listed materials are missing, see Information for MCI Students to find out how to get them. If you have everything that is listed, you are ready to "reconnoiter" your MCI course.

Read through the table(s) of contents of your text(s). Note the various subjects covered in the course and the order in which they are taught. Leaf through the text(s) and look at the illustrations. Read a few work unit questions to get an idea of the types that are asked. If MCI provides other study aids, such as a slide rule or a plotting board, familiarize yourself with them. Now, get down to specifics!

II. PLAN YOUR STUDY TIME AND CHOOSE A GOOD STUDY ENVIRONMENT

From looking over the course materials, you should have some idea of how much study you will need to complete this course. But "some idea" is not enough. You need to work up a personal study plan; the following steps should give you some help.

Ⓐ Get a calendar and mark those days of the week when you have time free for study. Two study periods per week, each lasting 1 to 3 hours, are suggested for completing the minimum two study units required each month by MCI. Of course, work and other schedules are not the same for everyone. The important thing is that you schedule a regular time for study on the same days of each week.



Ⓑ Read the course introduction page again. The section marked ORDER OF STUDIES tells you the number of study units in the course and the approximate number of study hours you will need to complete each study unit. Plug these study hours into your schedule. For example, if you set aside two 2-hour study periods each week and the ORDER OF STUDIES estimates 2 study hours for your first study unit, you could easily schedule and complete the first study unit in one study period. On your calendar you would mark "Study Unit 1" on the appropriate day. Suppose that the second study unit of your course requires 3 study hours. In that case, you would divide the study unit in half and work on each half during a separate study period. You would mark your calendar accordingly. Indicate on your calendar exactly when you plan to work on each study unit for the entire course. Do not forget to schedule one or two study periods to prepare for the final exam.

Ⓒ Stick to your schedule.

Besides planning your study time, you should also choose a study environment that is right for you. Most people need a quiet place for study, like a library or a reading lounge; other people study better where there is background music; still others prefer to study out-of-doors. You must choose your study environment carefully so that it fits your individual needs.

III. STUDY THOROUGHLY AND SYSTEMATICALLY

Armed with a workable schedule and situated in a good study environment you are now ready to attack your course study unit by study unit. To begin, turn to the first page of study unit 1. On this page you will find the study unit objective, a statement of what you should be able to do after completing the study unit.

DO NOT begin by reading the work unit questions and flipping through the text for answers. If you do so, you will prepare to fail, not pass, the final exam. Instead, proceed as follows:

Ⓐ Read the objective for the first work unit and then read the work unit text carefully. Make notes on the ideas you feel are important.

Ⓑ Without referring to the text, answer the questions at the end of the work unit.

Ⓒ Check your answers against the correct ones listed at the end of the study unit.

Ⓓ If you miss any of the questions, restudy the work unit until you understand the correct response.

Ⓔ Go on to the next work unit and repeat steps Ⓐ through Ⓓ until you have completed all the work units in the study unit.

Follow the same procedure for each study unit of the course. If you have problems with the text or work unit questions that you cannot solve on your own, ask your section OIC or NCOIC for help. If he cannot aid you, request assistance from MCI on the Student Course Content Assistance Request included with this course.

When you have finished all the study units, complete the course review lesson. Try to answer each question without the aid of reference materials. However, if you do not know an answer, look it up. When you have finished the lesson, take it to your training officer or NCO for mailing to MCI. MCI will grade it and send you a feedback sheet listing course references for any questions that you miss.

IV. PREPARE FOR THE FINAL EXAM

How do you prepare for the final exam? Follow these four steps:

Ⓐ Review each study unit objective as a summary of what was taught in the course.

Ⓑ Reread all portions of the text that you found particularly difficult.

Ⓒ Review all the work unit questions, paying special attention to those you missed the first time around.

Ⓓ Study the course review lesson, paying particular attention to the questions you missed.

If you follow these simple steps, you should do well on the final. GOOD LUCK!

STUDY UNIT 1

RADIO COMMUNICATIONS

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY THE BASIC COMPONENTS OF A RADIO SET. YOU WILL ALSO IDENTIFY RADIO WAVES, CARRIER WAVE, AND MODULATION. LASTLY, YOU WILL IDENTIFY WHAT DETERMINES THE FREQUENCY OF A RADIO WAVE.

Radio is the principal means of communications in many tactical units. It is used for command, fire control, exchange of information, administration, and liaison between and within units. Radio communications are particularly adaptable to rapidly changing situations. This is due to the fact that electromagnetic waves are used to convey signals between communication terminals without the use of wires. Communications with highly mobile units such as ships, aircraft, and tanks would be extremely difficult if radio were not available. The use of radio permits rapid installation and establishment of communications between locations separated by great distances and obstacles.

Work Unit 1-1. BASIC COMPONENTS OF A RADIO SET

STATE THE PURPOSE OF A RADIO TRANSMITTER.

STATE THE PURPOSE OF A RADIO RECEIVER.

STATE WHAT AN ANTENNA IS USED FOR.

STATE THE PURPOSE OF A POWER SUPPLY.

The basic components of a radio set are the transmitter, receiver, antenna, and power supply.

a. Transmitter. The device for sending out radio signals is called a transmitter. It generates, modulates, and radiates a radio frequency (RF) signal. A voice transmitter consists of an RF generator (oscillator), a power amplifier for increasing the power of the signal to the desired level, and a modulator for superimposing the intelligence onto the RF signal.

b. Receiver. The receiver takes the electromagnetic waves and develops an electrical signal, which is amplified and demodulated. This procedure is accomplished by minute currents entering the receiver from the antenna. A series of amplifiers (each with selective circuits) picks out the band of frequencies corresponding to the signal from a desired station and amplifies it to the desired level. This signal still contains variations corresponding to the original input, either in the form of frequency or amplitude modulation. A demodulator removes the intelligence from the carrier resulting in a signal. This signal is developed in the audio frequency range. This signal is further amplified to operate a loudspeaker or earphone, thus converting the electromagnetic waves back to an audible signal.

c. Antenna. The antenna provides a means for radiating RF energy into space. At the receiver location, it provides a means for intercepting (picking up) the radiated RF energy. If the receiver is tuned to the same frequency as the transmitted RF energy (signal), intelligence is made available. In transmission, the antenna operates as a load to the transmitter. It also operates as a signal source for the receiver in reception (receiving). The gain of an antenna, whether it's transmitting or receiving, depends on the design. The type of antenna, the site, and the type of ground used are of paramount importance in radio communications.

d. Power supply. Power supplies are devices that supply voltage to operate electronic equipment. A power supply is required by both the transmitter and receiver. Power supplies vary in size and electrical output, ranging from small dry cell batteries to diesel engine generators. The operating characteristics of a particular radio set determine the type, size, and output of the associated power supply.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What is the purpose of a radio transmitter?

____

____

2. What is the purpose of a radio receiver?

____

____

3. What is an antenna used for?

____

____

4. What is the purpose of a power supply?

____

Work Unit 1-2. RADIO WAVES

DEFINE RADIO WAVES.

STATE WHAT DETERMINES THE FREQUENCY OF A RADIO WAVE.

STATE THE FORMULA USED TO FIND THE WAVELENGTH WHEN THE FREQUENCY IS KNOWN.

Radio waves are electromagnetic energy radiating from an antenna. These waves travel near the surface of the earth and also radiate skyward at various angles to the surface of the earth. (fig 1-1) These electromagnetic waves travel through space at the speed of light, approximately 186,000 miles (300,000 kilometers (KM)) per second.

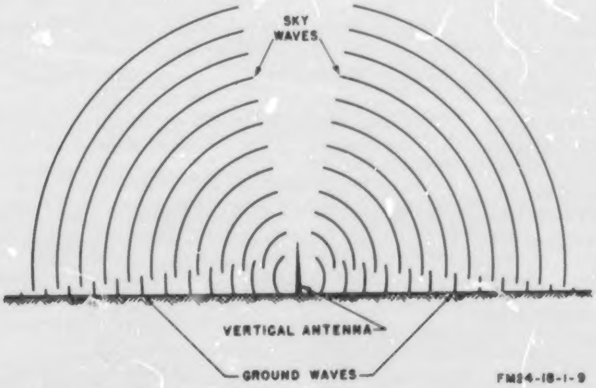


Fig 1-1. Radiation of radio waves from a vertical antenna.

The wavelength of a radio wave is the distance traveled by the wave in the period of time required to complete one cycle. Each complete cycle of two alternations of the wave is one wavelength expressed in meters (fig 1-2). This wavelength may be measured from the start of one wave to the start of the next wave, or from the crest of one wave to the crest of the next wave. In either case, the distance is the same.

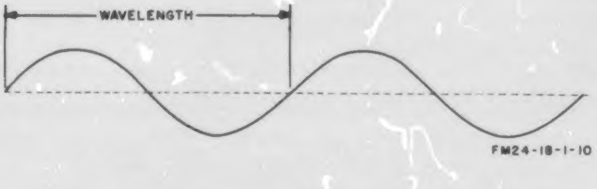


Fig 1-2. Wavelength of a radio wave.

The frequency of a radio wave is the number of complete cycles that occur in one second. The longer the time of one cycle, the longer the wavelength and the lower the frequency. The shorter the time of one cycle, the shorter the wavelength and the higher the frequency. The wavelength of a 2-MHz wave and a 10-MHz wave is demonstrated in fig 1-3.

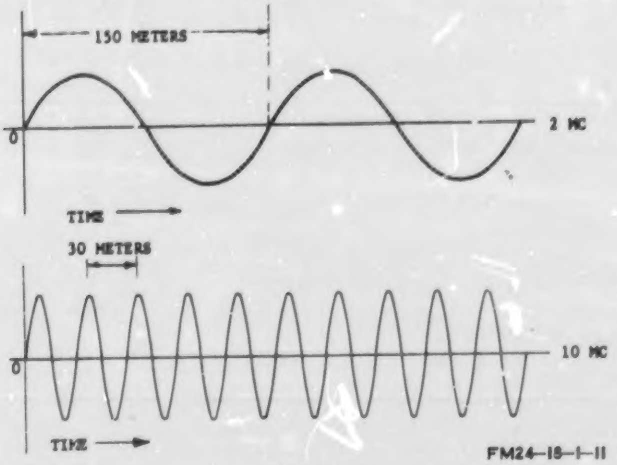


Fig 1-3. Comparison of two waves of different frequency.

Since the frequency of a radio wave is very great, it is expressed in kilohertz (KHz) per second or megahertz (MHz) per second. One KHz is equal to 1,000 cycles per second, and 1 MHz is equal to 1,000,000 cycles per second.

For practical purposes, the velocity of a radio wave is considered to be constant, regardless of the frequency or the amplitude of the transmitted wave. Therefore, to find the wavelength when the frequency is known, divide the velocity by the frequency.

$$\text{Wavelength (in meters) (free space)} = \frac{300{,}000{,}000 \text{ (meters per second)}}{\text{frequency (cycles per second)}}$$

$$= \frac{300{,}000}{\text{frequency (KHz)}}$$

$$= \frac{300}{\text{frequency (MHz)}}$$

To find the frequency when the wavelength is known, divide the velocity by the wavelength.

$$\text{frequency (cycles per second)} = \frac{300{,}000{,}000}{\text{wavelength (meters)}}$$

$$\text{frequency (KHz)} = \frac{300{,}000}{\text{wavelength (meters)}}$$

$$\text{frequency (MKz)} = \frac{300}{\text{wavelength (meters)}}$$

Most tactical radio sets operate within the 1.5 MHz to 400 MHz portion of the frequency spectrum. Radio frequencies are divided into groups or bands of frequencies for convenience of study and reference. The frequency bands of the radio spectrum are shown in table 1-1.

Table 1-1. Frequency Bands

Bands	Frequency (MHz)
Very low frequency (VLF)	Below .03
Low frequency (LF)	.03 to .3
Medium frequency (MF)	.3 to 3.0
High frequency (HF)	3.0 to 30
Very high frequency (VHF)	30 to 300
Ultrahigh frequency (UHF)	300 to 3,000
Superhigh frequency (SHF)	3,000 to 30,000
Extremely high frequency (EHF)	30,000 to 300,000

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Define Radio waves.

____

2. What determines the frequency of a radio wave?

____

____

3. To find the wavelength when the frequency is known, what is divided by the velocity?

____

Work Unit 1-3. CARRIER WAVES AND MODULATION

DEFINE CARRIER WAVE.

STATE THE PROCESS BY WHICH INFORMATION IS ATTACHED UPON A CARRIER WAVE.

DEFINE AMPLITUDE MODULATION.

DEFINE FREQUENCY MODULATION.

The radio transmitter supplies to the antenna a high frequency alternating current at a fixed level of intensity. This current is called the carrier wave or carrier. The carrier wave (fig 1-4) does not convey information, but acts as a medium for the transmission of information signal. The information in the form of a signal wave is superimposed upon the carrier, in which it "carries" the information.

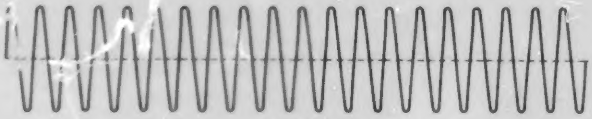


Fig 1-4. Carrier wave.

The process of superimposing the information upon the carrier is called modulation. This process varies or modifies either the frequency or the amplitude of the carrier waveform. Both amplitude modulation and frequency modulation methods are used in military radio communication systems.

When audio frequency (AF) signals are superimposed on the radio frequency (RF) carrier, additional RF signals are generated. The additional frequencies are equal to the sum, the difference of the audio frequencies and the radio frequency involved. For example, assume that a 1,000 KHz carrier is modulated by a 1 KHz audio tone. Two new radio frequencies are developed, one at 1,001 KHz (the sum of 1,000 and 1 KHz) and the other at 999 KHz (the difference between 1,000 and 1 KHz). If a complex audio signal is used instead of a single tone, two new frequencies will be set up for each of the audio frequencies involved. The new frequencies are called side bands.

Amplitude modulation (AM) is defined as the variation of the RF power output of a transmitter at an audio rate. In other words, the RF energy increases and decreases in power according to the audio (sound) frequencies. In simple terms, amplitude modulation is the process of varying the power output of a transmitter (fig 1-5).

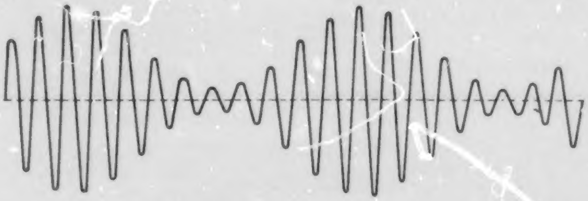


Fig 1-5. Amplitude modulated wave.

A radio frequency (RF) carrier is modulated by a single audio tone. In which, two additional frequencies are produced. One is the upper frequency, which equals the difference between the frequency of the RF carrier and the audio rate. The one higher than the carrier frequency is the upper side frequency. The one lower than the carrier frequency is the lower side frequency.

When the modulating signal is made up of complex tones, as in speech, each individual frequency component of the modulating signal produces its own upper and lower side frequencies. These side frequencies occupy a band of frequencies called side bands. The side band that contains the sum of the carrier and modulating frequencies is called the upper side band. The side band that contains the difference of the carrier and the modulating frequencies is called the lower side band.

The space that a carrier and its associated side bands occupy in the frequency spectrum is called a channel. In amplitude modulation, the width of the channel (bandwidth) is equal to twice the highest modulating frequency. Consequently, a 5,000-KHz carrier is modulated by a band of frequencies ranging from 200 to 5,000 cycles (.2 to 5 KHz), the upper side band extends from 5,000.2 to 5,005 KHz, and the lower side band extends from 4,999.8 to 4,995 KHz. The bandwidth is then 10 KHz, which is twice the highest modulating frequency (5 KHz).

The intelligence of an amplitude-modulated signal exists solely in the side bands, in which the amplitude varies according to the strength of the modulating signal.

Amplitude modulation generally is used by radiotelephone transmitters operating in the medium and high frequency portions of the spectrum.

Frequency modulation (FM) is the process of varying the frequency of the carrier wave (fig 1-6).

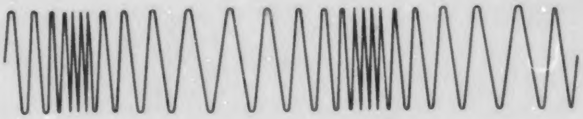


Fig 1-6. Frequency modulated wave.

In a frequency-modulated wave, the frequency varies instantaneously about the unmodulated carrier frequency in proportion to the amplitude of the modulating signal. Therefore, when the modulating signal increases in amplitude, the instantaneous frequency increase occurs; when the modulating signal decreases, the frequency decreases.

In an FM wave, the amplitude of the modulating signal determines the extent of departure of the instantaneous frequency from the center or rest frequency. Thus, the instantaneous frequency can be made to deviate as much as desired from the carrier frequency by changing the amplitude of the modulating signal. Even though the modulation frequency is only a few kilohertz, this deviation frequency may be as high as several hundred kilohertz. The side-band pairs generated by frequency modulation are not restricted, as in amplitude modulation, to the sum and difference between the highest modulating frequency and the carrier.

The first pair of side-bands in an FM signal are the carrier frequency, plus and minus the modulating frequency. Additional side-band pairs will appear at each multiple of the modulating frequency. For example, a carrier of 1 MHz is frequency modulated by an audio signal of 10 KHz. There will be several side-band pairs spaced equally on either side of the carrier with frequency at 999 KHz/1,010 KHz, 980 KHz/1,020 KHz, 970 KHz/1,030 KHz, and continuing in the same process. As a result, a frequency modulated signal occupies a greater bandwidth than a amplitude-modulated signal.

As indicated above, the FM wave consists of a center or carrier frequency and a number of side-band pairs. When modulation is applied, the amplitude of the modulation signal increases in which power takes place from the center-frequency component and is forced into the side-band pairs.

The FM signal leaving the transmitting antenna is constant in amplitude, but varies in frequency according to the audio-modulating signal. The signal travels between the transmitting and receiving antennas; however, it is combined with natural and man-made noises that cause amplitude variations in the signal. All of these undesirable amplitude variations are amplified as the signal passes through successive stages of the receiver until the signal reaches the limiter stage.

The limiter eliminates amplitude variations and passes the FM signal on to the discriminator, in which the discriminator is sensitive to variations in the frequency of an RF wave. The resultant constant-amplitude frequency-modulated signal is processed by the discriminator circuit, which transforms the frequency variations of the signal into corresponding voltage amplitude variations. These voltage variations reproduce the original modulating signal in a reproducing device such as a headset, loudspeaker, or teletypewriter.

Frequency modulation generally is used by radiotelephone transmitters operating in the very high frequency bands.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. The wave upon which all information is attached or superimposed for transmission defines ______________________________.

2. When intelligence has been applied to a carrier, the carrier is said to be ______________________________.

3. The process of varying the RF power output of a transmitter defines ______________________________.

4. The process of varying the frequency of the carrier wave defines ______________________________.

SUMMARY REVIEW

In this study unit, you have learned about the basic components of a radio set. You have learned that radio waves are electromagnetic energy which radiate from an antenna. You have also learned that a carrier wave acts as a medium for the transmission of information signals and that these signals are superimposed upon the carrier wave by means of modulation, either amplitude or frequency.

Answers to Study Unit #1 Exercises

Work Unit 1-1.

1. To send out radio signals
2. The receiver takes the electromagnetic waves and develops an electrical signal, which is then amplified and demodulated into an audible signal.
3. It provides a means for radiating RF energy into space and picking up the radiated RF energy.
4. Supplies the voltage needed to operate electronic equipment

Work Unit 1-2.

1. electromagnetic energy radiated from an antenna.
2. The number of complete cycles that occur in one second
3. frequency

Work Unit 1-3.

1. carrier wave
2. modulated
3. amplitude modulation
4. frequency modulation

STUDY UNIT 2

PROPAGATION OF RADIO WAVES

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY ATMOSPHERE AND THE THREE LAYERS WHICH MAKE UP THE EARTH'S ATMOSPHERE. YOU WILL IDENTIFY GROUND WAVE PROPAGATION, SKY-WAVE PROPAGATION, AND SKIP ZONE. IN ADDITION, YOU WILL IDENTIFY THE IONOSPHERE AND TELL WHY IT'S SO IMPORTANT TO LONG RANGE COMMUNICATIONS. YOU WILL ALSO IDENTIFY MAXIMUM USABLE FREQUENCY (MUF), LOWEST USABLE FREQUENCY (LUF), AND FADING. LASTLY, YOU WILL IDENTIFY THE EFFECTS THAT FREQUENCY HAS ON WAVE PROPAGATION.

Radio communications is not the same at all hours of the day or at all times of the year. Even though radio waves and the atmosphere above the earth are invisible, the atmosphere plays an important role in radio communications. Things happening on the sun such as sun spots, being several million miles away, also have a direct effect on communications. Since propagation usually takes place within the earth's atmosphere, it is necessary to establish a basic understanding of the air around and above us.

Work Unit 2-1. THE ATMOSPHERE

DESCRIBE THE ATMOSPHERE.

NAME THE THREE LAYERS WHICH MAKE UP THE ATMOSPHERE.

GIVEN A LIST OF THE ATOMOSPHERE LAYERS AND A LIST OF THE DESCRIPTION, MATCH EACH LAYER WITH ITS APPROPRIATE DESCRIPTION.

The Atmosphere

Wave propagation deals with the properties and the nature of the atmosphere through which radio waves must travel from the transmitting antenna to the receiving antenna. The atmosphere is a gaseous mass which envelops the earth. It is not uniform, because it varies with the altitude, geographic location, time of day or night, season, and year. A knowledge of the composition and properties of the atmosphere aids in the solution of problems that arise in planning radio communication paths and in predicting the reliability of communications. The earth's atmosphere is divided into three regions: the troposphere, the stratosphere, and the ionosphere. For an idea of their location and heights above the earth see figure 2-1.

a. Troposphere. The troposphere is that portion of the earth's atmosphere extending from the surface of the earth to a height of approximately 6.8 miles (10 km). Within the troposphere, the bending of radio waves by refraction causes the radio horizon to exceed the optical horizon. Troposphere refraction (reflection caused by sudden changes in the characteristics of air in a lower atmosphere) affect the received signal at distances beyond the radio horizon.

b. Stratosphere. The stratosphere is that portion of the earth's atmosphere lying between the troposphere and ionosphere, about 6.8 miles to 30 miles (10 to 48 km) above the earth. The temperature in this region is nearly constant.

c. Ionosphere. The ionosphere is that portion of the earth's atmosphere above the lowest level at which ionization (splitting of molecules into positive and negative charges or ions) of low pressure gasses will affect the transmission of radio waves. It extends from about 30 to 250 miles (48 to 402 km) above the earth. The ionosphere is composed of several distinct layers in which ionization occurs at different levels and intensities.

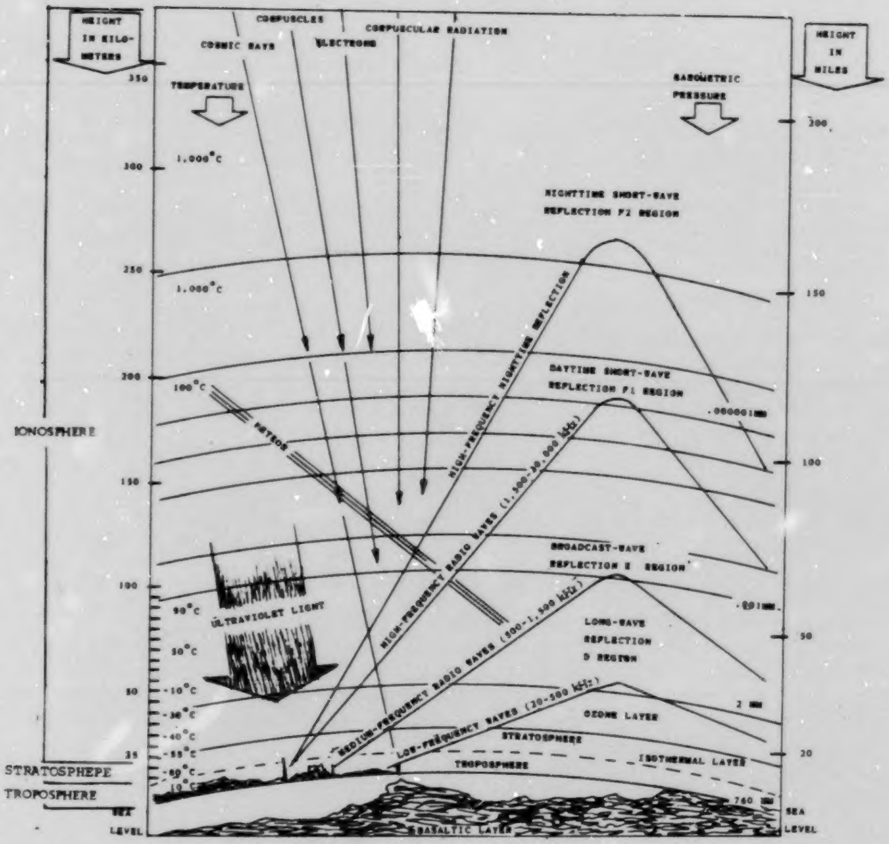

HEIGHT IN KILOMETERS
COSMIC RAYS
CORPUSCLES
ELECTRONS
CORPUSCULAR RADIATION
HEIGHT IN MILES
TEMPERATURE
BAROMETRIC PRESSURE
350
300
250
200
150
100
50
35
1,000°C
1,000°C
100°C
90°C
30°C
-10°C
-30°C
-40°C
-55°C
-60°C
10°C
200
150
100
50
20
IONOSPHERE
STRATOSPHEPE
TROPOSPHERE
SEA LEVEL
NIGHTTIME SHORT-WAVE REFLECTION F2 REGION
DAYTIME SHORT-WAVE REFLECTION F1 REGION
METEOR
HIGH-FREQUENCY NIGHTTIME REFLECTION
HIGH-FREQUENCY RADIO WAVES (1,500-30,000 kHz)
.000001mm
BROADCAST-WAVE REFLECTION E REGION
ULTRAVIOLET LIGHT
MEDIUM-FREQUENCY RADIO WAVES (500-1,500 kHz)
.01mm
LONG-WAVE REFLECTION D REGION
LOW-FREQUENCY WAVES (20-500 kHz)
2 mm
OZONE LAYER
STRATOSPHERE
ISOTHERMAL LAYER
TROPOSPHERE
760 mm
BASALTIC LAYER
SEA LEVEL

Fig 2-1. The earth's atmosphere.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. The atmosphere is a____
____.

2. The three regions or layers which make up the earth's atmosphere are the__________
____________, _________________________, and ________________________.

Matching: Column 1 (items 3 through 5) lists the atomospheric layers. Column 2 (a through c) lists the description of the atomospheric layers. Match each atomospheric layer in column 1 with the description in column 2. Place your answers in the spaces provided.

Column 1 Atomospheric layers	Column 2 Description
____3. Troposphere	a. The region of the atomosphere which extends from the surface of the earth to a height of about 6.8 miles
____4. Ionosphere	b. The region of the earth's atomosphere composed by several distinct layers
____5. Stratosphere	c. The region of earth's atomosphere where the temperature remains nearly constant

Work Unit 2-2. GROUND WAVES, SKY WAVES, AND SKIP ZONE

DEFINE GROUND-WAVE PROPAGATION.

NAME THE THREE COMPONENTS OF A GROUND WAVE.

STATE WHAT SKY-WAVE PROPAGATION DEPENDS UPON.

DEFINE SKIP ZONE.

Ground-Wave Propagation

Ground-wave propagation refers to those types of radio transmission that do not make use of waves that have been refracted from the ionosphere. The field intensity of ground waves depends on the transmitter power, the characteristics of the transmitting antenna, the frequency of the waves, the diffraction of the waves around the curvature of the earth, the electrical characteristics (conductivity and dielectric constant) of the local terrain, the nature of the transmission path, and local weather conditions. The following are three components of a ground wave.

a. Direct Wave. The direct wave is that component of the entire wave front that travels directly from the transmitting antenna to the receiving antenna (fig 2-2). This component is limited to the line-of-sight distance between the transmitting and receiving antennas, plus the small distance added by atmospheric refraction and diffraction of the wave around the curvature of the earth. This distance can be extended by increasing the height of the transmitting antenna or the receiving antenna (or both).

b. Ground-Reflected Wave. The ground-reflected wave (fig 2-2), is the portion of the radiated wave that reaches the receiving antenna after being reflected from the surface of the earth. When both the transmitting and receiving antennas are on or close to the ground, the direct and ground-reflected components of the ground wave tend to cancel each other.

c. Surface Wave. The surface wave (fig 2-2) which follows the curvature of the earth, is the component of the ground wave that is affected by the conductivity and dielectric constant of the earth.

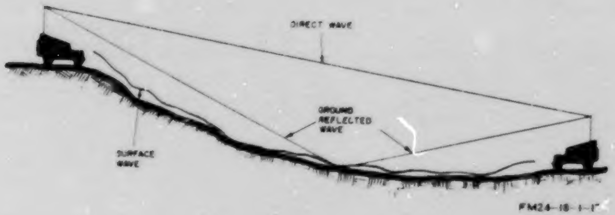


Fig 2-2. Possible routes for ground waves.

Sky-Wave Propagation

a. Sky-wave transmission paths. Sky-wave propagation refers to those types of radio transmission that depend on the ionosphere to provide signal paths between transmitters and receivers (fig 2-3). Sky-wave transmissions are by far the most important method for long distance radio communications.

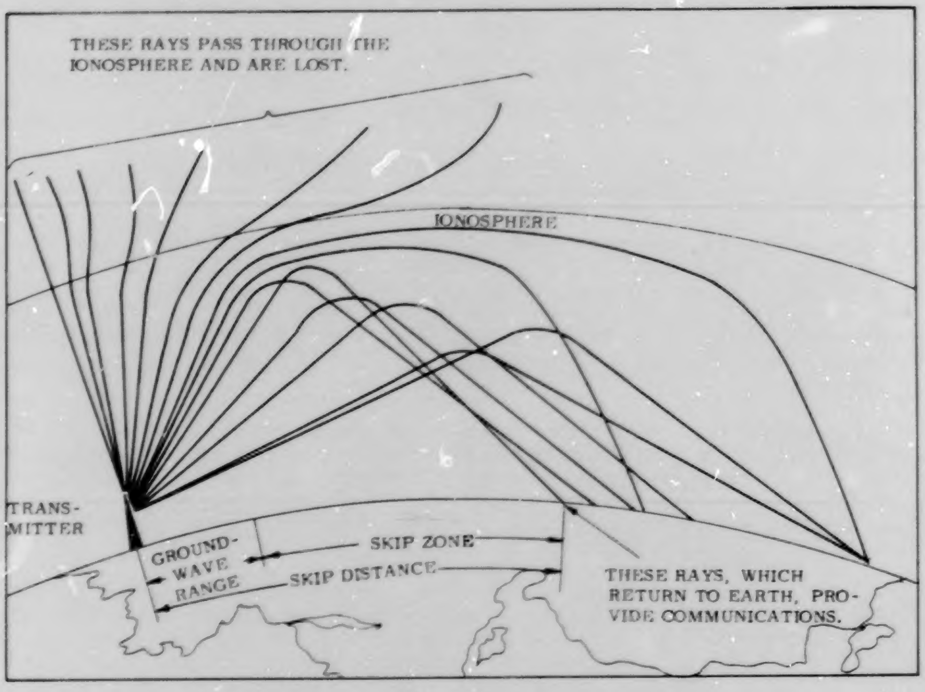

THESE RAYS PASS THROUGH THE IONOSPHERE AND ARE LOST.
IONOSPHERE
TRANS-MITTER
GROUND-WAVE RANGE
SKIP ZONE
SKIP DISTANCE
THESE RAYS, WHICH RETURN TO EARTH, PROVIDE COMMUNICATIONS.

Fig 2-3. Various sky-wave transmission paths.

b. Sky-Wave Modes. The distance at which the wave returns to the earth depends on the height of the ionized layer and the amount of bending of the path while traversing the layer; the latter depending on the frequency of the wave as compared to the ion density of the layer required to refract or bend the wave. Upon return to the earth's surface, part of the energy enters the earth to be rapidly dissipated, but part is reflected back into the ionosphere again, where it may reflect downward again at a still greater distance from the transmitter. This means of travel in hops, by alternate reflections from the ionosphere and from the surface of the earth, may continue, and enables transmission to be received at long distances from the transmitter. Figure 2-4 illustrates this means of travel for paths involving one, two, or three reflections from the ionosphere (single, double and triple hop modes or paths).

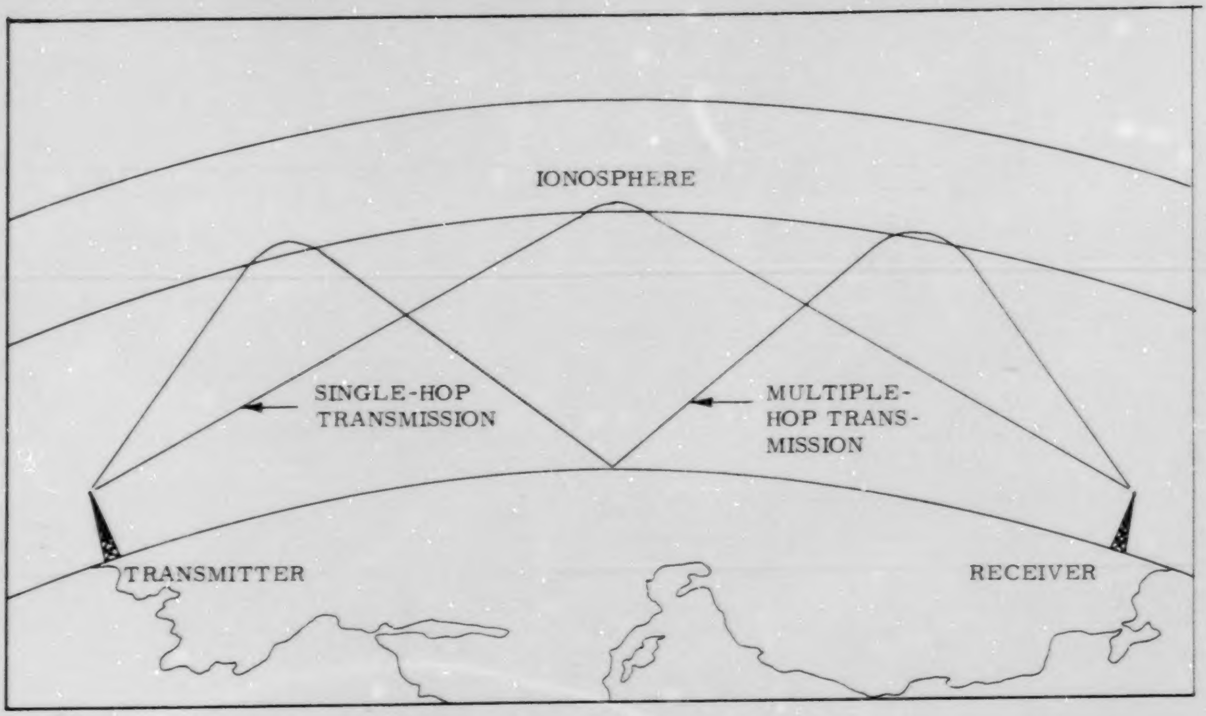


Fig 2-4. Modes of sky-wave tranmissions.

Figure 2-5 further illustrates this means of travel and reflection from different layers, with the layers represented by line for simplicity. Figure 2-4 also relates the heights of the various ionized layers to actual distances along the earth's surface.

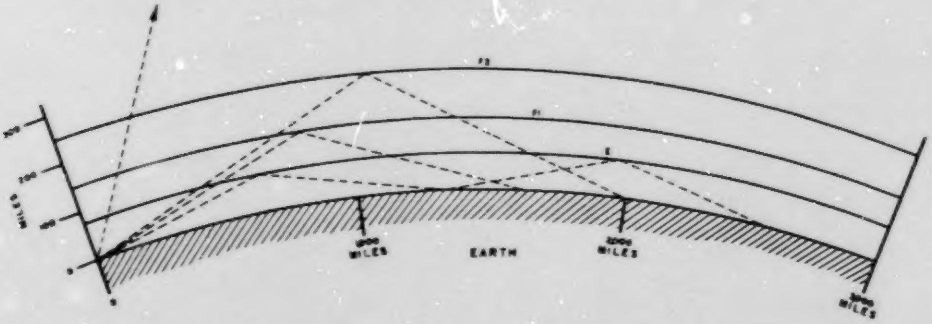


Fig 2-5. Relating reflected waves to distances along earth's surface.

c. Skip Zone. The skip zone is an area where no usable signal can be received from a given transmitter operating at a given frequency. This area is bounded by the outer edge of the usable ground-wave propagation and the point nearest the antenna at which the sky wave returns to earth--the skip distance. The skip zone and its relation to the ground wave are shown in figure 2-6. When the skip distance is within the range of the ground wave, there is no skip zone. In this case, both the sky wave and the ground wave may arrive at the antenna with nearly the same field intensity but a random relative phase. When this occurs, the sky-wave component alternately reinforces and cancels the ground-wave component, causing severe blasting (during reinforcement) and fading (during cancellation) of the signal. For each frequency (greater than the critical frequency) at which refraction from an ionosphere layer takes place, there is a skip distance that depends only on the frequency and the state of ionization. The skip zone, on the other hand depends on the extent of the ground-wave range, and disappears completely if the ground-wave range exceeds the skip distance.

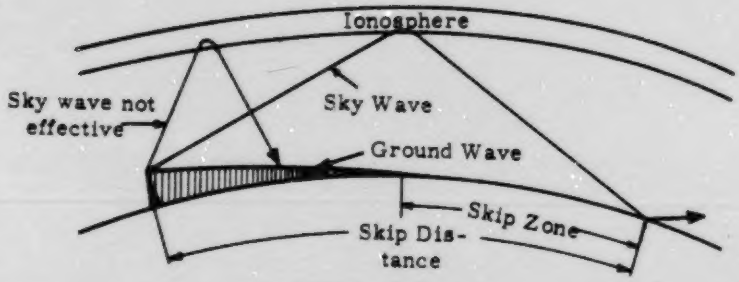


Fig 2-6. Skip zone.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Define ground-wave propagation.

   ____

2. What are the three components of the ground wave?

   a. ______________________________

   b. ______________________________

   c. ______________________________

3. Sky-wave propagation depends on the ______________________________

   ____________________ to provide signal paths between transmitter and receivers.

4. Define skip zone.

   ____

Work Unit 2-3. THE LAYERS OF THE IONOSPHERE

STATE THE GENERAL EFFECT THAT THE "D" REGION HAS ON HIGH FREQUENCY RADIO WAVES.

STATE THE REGION WHICH IS IONIZED AT ALL HOURS OF THE DAY AND NIGHT.

STATE WHAT DETERMINES THE RANGE OF LONG DISTANCE RADIO TRANSMISSIONS.

NAME THE TWO LAYERS OF THE IONOSPHERE WHICH ARE MOST HIGHLY IONIZED.

DEFINE CRITICAL FREQUENCY.

Ionosphere. The ionosphere is that portion of the earth's atmosphere containing ionized gases. There are four distinct layers of the ionosphere. In the order of increasing heights and intensities, they are called the "D," "E," "F1," and "F2" layers. The relative distribution of these layers is shown in figure 2-7. As may be seen in the illustration, the four layers are present only during the day when the rays of the sun are directed toward that portion of the atmosphere. During the night, the "F1" and "F2" layers seem to merge into a single "F" layer, and the "D" and "E" layers fade out. The actual member of layers, their heights above the earth, and the relative intensity of ionization present in them vary from hour to hour, day to day, month to month, season to season, and year to year.

a. "D" Region. The "D" region exists only during daylight hours and has little effect in bending the path of high frequency radio waves. The main effect of the "D" region is to attenuate or decrease the intensity of high-frequency waves when the transmission path lies in sunlit regions.

b. "E" Region. The "E" region is used during the day for high-frequency radio transmission over intermediate distances (less than approximately 1,500 miles). The intensity of this layer decreases during the night; however, and it becomes useless for radio transmission.

c. "F" Region. The "F" region exists at heights up to 240 miles (380 km) above the surface of the earth and is ionized at all hours of the day and night. There are two well-defined layers during the day and one during the night. At night, the "F" layer lies at a height of about 170 miles (260 km) and is useful for long-range radio communication (over 1,500 miles (2400 km)).

d. "F1" and "F2" Layers. During the day the "F" region splits into two distinct layers, the "F1" layer and the "F2" layer. The "F2" layer is the most useful of all layers for long-range radio communication, even though the degree of ionization varies appreciably from day to day as compared with other layers.

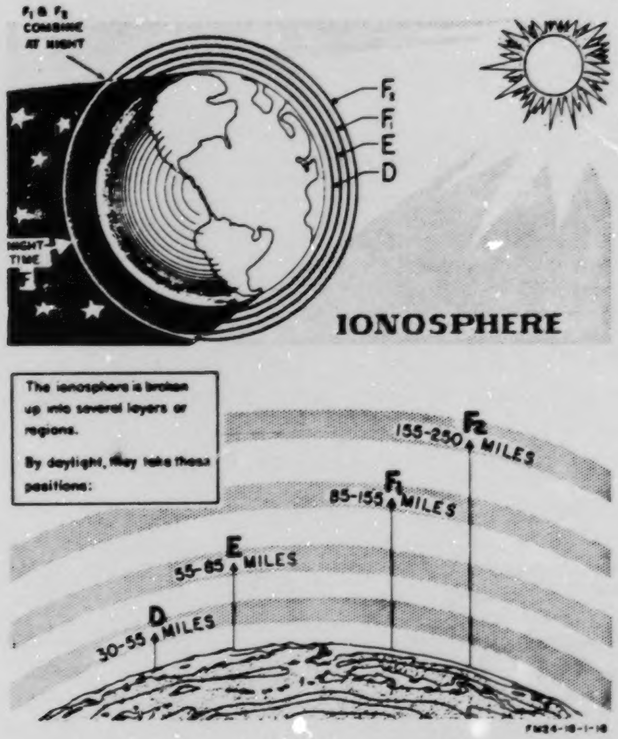

F_1 & F_2 COMBINE AT NIGHT
F_2
F_1
E
D
NIGHT-TIME F
IONOSPHERE
The ionosphere is broken up into several layers or regions.
By daylight, they take these positions:
F_2 155-250 MILES
F_1 85-155 MILES
E 55-85 MILES
D 30-55 MILES
FM24-18-1-18

Fig 2-7. Average layer distribution of the ionosphere.

Ionosphere Characteristics

a. Critical Frequency. The range of long-distance radio transmission is determined primarily by the ionization density of each of the layers. The higher the frequency, the greater density of ionization required to refract radio waves back to earth. The upper ("E" and "F") layers refract the higher frequencies because they are the most highly ionized. The "D" layer, which is the least ionized does not refract frequencies above approximately 500 KHz. Thus, at any given time and for each ionized layer, there is an upper frequency limit at which waves sent vertically upward are reflected directly back to earth. This limit is called the critical frequency. Waves that are directed vertically at frequencies higher than the critical frequency pass through the ionized layer out into space. All waves directed to the ionosphere at frequencies lower than the critical frequency are refracted back to the earth.

b. Critical Angle. Radio waves used in communication generally are directed to the ionosphere at some oblique angle called the angle of incidence. Waves at frequencies above the critical frequency will be returned, if propagated at angles of incidence lower than the critical angle. At the critical angle, and at all angles larger than the critical angle, the wave will pass through the ionosphere, if the frequency is higher than the critical frequency. As the angle becomes smaller, an angle is reached at which the wave is bent back to the earth by refraction. The distance between the transmitting antenna and the point at which the wave first returns is called the skip distance (fig 2-3).

Variations of the Ionosphere

The movements of the earth around the sun and changes in the sun's activity contribute to ionospheric variations. There are two main classifications of these variations: regular variations that are predictable, and irregular variations resulting from abnormal behavior of the sun.

a. Regular Variations. The regular variations may be divided into four classes: (1) the daily, caused by the rotation of the earth; (2) the seasonal, caused by the north and south progression of the sun; (3) the 27-day, caused by the rotation of the sun on its axis; and (4) the 11-year, which is the average period during which sunspot activity varies from maximum to minimum and back to maximum.

b. Irregular Variations. The transient (momentary) ionospheric variations, though unpredictable, have important effects on radio propagation. Some of these effects are:

(1) Sporadic E. When it is excessively ionized, the E layer often completely blanks out the reflections from the higher layers. This effect may occur during the day or at night.

(2) Sudden ionospheric disturbance. A sudden ionospheric disturbance (SID) coincides with a bright solar eruption and causes abnormal ionization of the D layer. This effect causes total absorption of all frequencies above 1 MHz. It occurs without warning during the day and may last from a few minutes to several hours. When SID occurs, receivers seem to go dead.

(3) Ionosphere storms. These storms may last from several hours to several days, and usually extend over the entire earth. During these storms, sky-wave transmission above approximately 1.5 MHz shows low intensity and is subject to a type of rapid blasting and fading called flutter fading.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What general effect does the "D" region of the ionosphere have on high frequency radio waves?

____

2. Which region of the ionosphere is ionized at all hours of the day and night?

____

3. What determines the range of long distance radio transmissions?

____

4. The two layers of the ionosphere highly ionized are:

a. ______________________________

b. ______________________________

5. Define critical frequency.

____

____.

Work Unit 2-4. MAXIMUM USABLE FREQUENCY (MUF) AND LOWEST USABLE FREQUENCY (LUF)

DEFINE MAXIMUM USABLE FREQUENCY (MUF).

STATE WHAT WOULD HAPPEN TO WAVES OF FREQUENCY GREATER THAN THE MUF.

DEFINE LOWEST USABLE FREQUENCY (LUF).

Maximum Usable Frequency (MUF)

An important concept associated with sky-wave propagation is called the maximum usable frequency (MUF). MUF is the highest frequency for which a radio wave will reflect from an ionospheric layer for a given elevation or propagation path. Frequencies higher than the MUF will penetrate the layer and escape into space.

It is important at this point to discuss propagation predictions and their statistical nature. The science of predicting ionospheric conditions and the best frequencies to use for a given path is well developed, but subject to the same accuracy problems as prediction of the local weather. It is impossible to predict with absolute accuracy what frequency will be best to use for a given propagation path. It is impossible to predict with reasonable good accuracy what the MUF will be for a given communication path at a particular time of day. These predictions are usually based on a statistical reliability of 50 percent . For example, assume that the MUF for a certain propagation path is predicted to be 12 MHz during the time period of 1200 to 1600 hours for the month of November. This actually means that the MUF will be lower than 12 MHz 15 days of the month and higher than 12 MHz the other 15 days of the month. The median MUF for the entire month will be 12 MHz. It also means that, on a given day when the MUF is actually 12 MHz, frequencies slightly higher than 12 MHz may be used with greatly reduced reliability.

When there is a choice of frequencies to use, it is always best to use higher frequency. This is especially true when communicating over distances greater than about 1,000 km. This reduces absorption from any lower layer and minimizes multi-path fading. However, it is generally undesirable to operate at or near the MUF, since this frequency is reflected only 50 percent of the time. To allow for day to day changes in the MUF and the critical frequency, it is customary to use a frequency that is about 85 percent of the MUF. This lower frequency is known as the frequency of optimum transmission (FOT). It is based on the statistical fact that it lies below the daily variations of the actual MUF about 90 percent of the time. It is not always the frequency for minimum path loss or for minimun fading, and there are times when a frequency 10 percent lower or higher than the FOT will be better. However, based on statistics, the FOT represents the best choice for a given path length, time of day, season, and sunspot number, see figure 2-8.

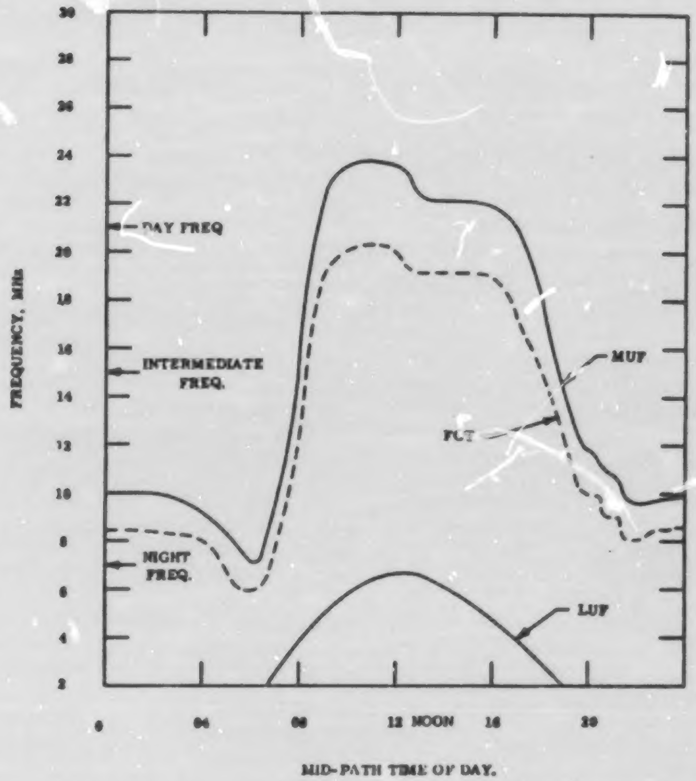


Fig 2-8. Typical variation of LUF, FOT, and MUF over a path from London to the Canary Islands during the month of December.

Lowest Usable Frequency (LUF)

For a given transmitter power, as the operating frequency is decreased, the average signal level at the receiver will decrease due to increased ionospheric absorption. The average level of natural atmospheric noise (lightning discharge) and man-made noise (electrical equipment) existing at the receiver location increases at lower frequencies. Thus, if the frequency of transmission is reduced much below the critical frequency, the received signal strength decreases while the received noise increases until finally the signal is generally unusable. As the frequency for transmission over any given sky-wave path is increased, a value will be reached at which the received signal just overrides the level of atmospheric and other radio noises. This is called the lowest usable frequency (LUF) because frequencies lower than the LUF are too weak for useful communications. The LUF depends upon the power of the transmitter, path loss, total noise level at the receiving location, receiving antenna gain and directivity, and noise generated within the receiver itself. Because ionospheric absorption is maximum when the "D" layer reaches its peak, the LUF generally peaks around noon. A frequency for day use must be chosen sufficiently above the LUF to ensure a reliable signal-to-noise ratio.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Define maximum usable frequency.

____

____

2. What happens to waves of frequency greater than the MUF?

____

3. Define lowest usable frequency.

____

Work Unit 2-5. FADING

DEFINE FADING.

Fading is the periodic increase and decrease of received signal strength. This occurs when a radio signal is received over a long distance path in the high frequency range. The precise origin of this fading is seldom understood. There is little common knowledge of what precautions can be taken to reduce or eliminate the troublesome effects of fading. Suggested methods for reducing fading are: increasing transmitter power and antenna gain, using two or more receiving antennas spaced some distance apart both feeding into the same receiver (diversity reception), and proper frequency selection and intelligent use of transmitting and receiving equipment. Fading associated with sky-wave paths is the greatest single detriment to reliable communications.

The many types of fading fall into four principal classes: interference, polarization, absorption, and skip fading. Most of the rapid fading in the input to a receiver is a combination of the first two types; the other two are responsible for slower changes.

a. Interference Fading. Interference fading is caused by phase interference of two or more waves from the same source arriving at the receiver over slightly different paths. If the paths are of different lengths, and their relative lengths vary for some reason, such as fluctuations in the height of the ionosphere layers, the relative phases of the waves arriving over the different paths vary with time, causing alternate reinforcement and cancellation of the field intensity (fig 2-9). Because of irregularities in the ionosphere, one downcoming sky wave is really the summation of a great number of waves of small intensity and of random relative phases, and thus the resultant field intensity can vary over wide limits.

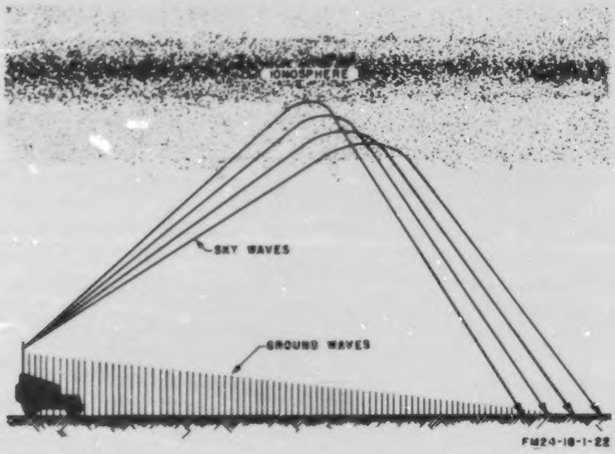


Fig 2-9. Fading caused by combination of ground and sky waves.

b. Polarization Fading. Additional variation in the field intensity affecting the receiving antenna occurs as a result of changes in the state of polarization of the downcoming wave relative to the orientation of the antenna. This variation is called polarization fading. In general, the state of polarization of the downcoming sky wave is changing constantly. This is due mainly to the combination, at random amplitudes and phases, of the two oppositely polarized components, the ordinary and the extraordinary wave. The polarization of the downcoming sky wave is generally elliptical. Elliptical polarization means that as the wave travels along the signal path, the electric and magnetic fields remain at right angles to each other and to the direction of propagation, but rotate about the signal path in more or less corkscrew fashion instead of remaining constantly in either a vertical or a horizontal plane with respect to the path, as does the plane polarized wave. This results in random and constantly changing values of the amplitude and orientation of the electric field with respect to the receiving antenna. The state of polarization of sky waves varies more rapidly the higher the frequency, which accounts in part for the rapid fading on the higher frequencies.

c. Absorption Fading. Absorption fading is caused by short-time variations in the amount of energy lost from the wave because of absorption in the ionosphere. In general, the period of this type of fading is much longer than for the other two types, since the ionospheric absorption usually changes slowly. The sudden ionospheric disturbance is an extreme case of this type of fading, although usually it is classified as an irregular disturbance rather than as fading. Somewhat similar to this type of fading, although not caused in the ionosphere but by reflections and absorption in objects close to the receiver, is the type of fading experienced in receiving a signal while moving along in a vehicle. The fading out of the signal when the vehicle is passing under a bridge or near a heavy steel structure is caused by absorption of the wave's energy by the structure. Effects of this sort are involved in so-called dead spots or places where radio reception is particularly difficult. Also, radiation from wires, fences, and steel structures can cause an interference pattern that is relatively fixed in space, and can be noticed on moving the receiving equipment around. Where there are nearby structures which can cause these effects, care must be exercised in the selection of the receiving site.

d. Skip Fading. Skip fading is observed at places near the limit of the skip distance, and is caused by the changing angle of refraction. Near sunrise and sunset, when the ionization density of the ionosphere is changing, it may happen that the MUF for a given transmission path fluctuates about the actual operation frequency. When the skip distance moves out past the receiving station (sometimes called going into the skip) the received intensity abruptly drops by a factor of 100 or more, and just as abruptly increases again when the skip distance moves in again. This may take place many times before steady conditions for transmission are established.

EXERCISE: Answer the following question and check your response against those listed at the end of this study unit.

1. Define fading.

____

Work Unit 2-6. EFFECTS OF FREQUENCY ON WAVE PROPAGATION

STATE THE WAVE PROPAGATION THAT IS EXTREMELY USEFUL FOR COMMUNICATION AT LOW FREQUENCIES.

STATE THE TWO TYPES OF WAVE PROPAGATION THAT ARE USEFUL AT THE MEDIUM FREQUENCY BAND.

STATE THE TWO TYPES OF WAVE PROPAGATION THAT ARE PRESENT AT THE HIGH FREQUENCY BAND.

STATE THE WAVE PROPAGATION THAT PROVIDES THE BEST COMMUNICATIONS AT THE VERY HIGH FREQUENCY BAND.

STATE THE WAVE PROPAGATION THAT MUST BE USED FOR ALL TRANSMISSIONS AT ULTRA HIGH FREQUENCIES.

The understanding of the effects of the atmospheric layers described in work units 2-1 through 2-5 is complicated further by variations in frequency of the transmitted wave. The characteristics of low-frequency propagation are different from high-frequency propagation. The frequencies of propagation usually are classed in ranges shown in table 1-1 for ease of identification. There are two principal ways stated earlier in work unit 2-2, in which radio waves travel from a transmitter to a receiver by means of ground waves and sky waves.

At low frequencies (.03 to .3 MHz), the ground wave is extremely useful for communication over greater distance. The ground wave signals are quite stable and show little seasonal variation. In the medium-frequency band (.3 to 3.0 MHz), the range of the ground wave varies from about 15 miles (24 km) at 3000 KHz to about 400 miles (640 km) at the lower frequencies of the band. Sky wave reception is possible during day or night at any of the lower frequencies in this band. At night, the sky wave gives reception at a distance up to 8,000 miles (12,870 km). In the high-frequency band (3.0 to 30 MHz), the range of the ground wave decreases with an increase in frequency and the sky waves are greatly influenced by ionospheric considerations. In the very-high-frequency band (30 to 300 MHz), there is no usable ground reflected and no surface wave, only a slight refraction of sky waves by the ionosphere at the lower frequencies. The direct wave provides communication if the transmitting and receiving antennas are elevated sufficiently above the surface of the earth. Transmission over any greater range is unpredictable and will last only for short periods of time, because of sporadic conditions in the ionosphere. In the ultra-high-frequency band (300 to 3,000 MHz), the direct wave must be used for all radio transmissions. Communication is limited to a short distance beyond the horizon. Lack of static and fading in these bands makes line-of-sight reception very satisfactory. Highly directive antennas can be built into small spaces to concentrate RF energy into a narrow beam, thus increasing the signal intensity.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What wave propagation is useful for communications at low frequencies?

2. What two types of wave propagation are useful at the medium frequency band?

   a.

   b.

3. What two types of waves propagation are present in the high frequency band?

4. What propagation wave or component of a propagation wave provides the best communication at the very-high-frequency range?

5. When operating within the UHF band, which component of the ground wave provides communication?

SUMMARY REVIEW

In this study unit, you have learned about the earth's atmosphere and the three different layers which make up the atmosphere. You have learned about ground-wave, sky-wave propagation, skip zones, and how the ionosphere affects long distance sky wave transmissions. You have also learned about the affect fading has on long distance communications and the different propagation paths associated with the different frequency ranges (bands).

Answers to Study Unit #2 Exercises

Work Unit 2-1.

1. gaseous mass which envelops the earth
2. troposphere, stratosphere, ionosphere
3. a.
4. b.
5. c.

Work Unit 2-2.

1. those types of radio transmission that do not make use of waves that have not been refracted from the ionosphere.
2. a. Direct wave
   b. Ground reflected wave
   c. Surface wave
3. ionosphere
4. An area where no usable signal can be received from a given transmitter operating at a given frequency

Work Unit 2-3.

1. Little
2. The "F" region
3. The ionization density of each region within the ionosphere
4. a. "E" layer
   b. "F" layer
5. The highest frequency at which waves sent vertically upward are reflected directly back to earth

Work Unit 2-4.

1. The highest frequency for which a radio wave will reflect from an ionospheric layer for a given elevation or propagation path
2. The wave will penetrate the layer and escape into space.
3. A frequency at which the transmitted/received signal just overrides the level of atmospheric and other radio noises, allowing the signal/intelligence to be understood at the receiver.

Work Unit 2-5.

1. The periodic increase and decrease of received radio strength

Work Unit 2-6.

1. Ground wave
2. a. Ground wave
   b. Sky wave
3. a. Ground wave
   b. Sky wave
4. Direct wave
5. Direct wave

STUDY UNIT 3

ANTENNAS

STUDY UNIT OBJECTIVES: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY THE FUNCTIONS OF AN ANTENNA, THE COMPONENTS OF THE RADIATION FIELD AND ANTENNA POLARIZATION. IN ADDITION, YOU WILL IDENTIFY THE POLARIZATION REQUIREMENTS FOR VARIOUS FREQUENCIES AND THE ADVANTAGES AFFORDED WHEN USING EITHER VERTICAL OR HORIZONTAL POLARIZATION. YOU WILL ALSO IDENTIFY THE CONVENTIONAL FIELD ANTENNAS USED WITHIN THE MARINE CORPS, AND SEVEN TYPES OF FIELD EXPEDIENT ANTENNAS. LASTLY, YOU WILL IDENTIFY THE VARIOUS TYPES OF TRANSMISSION LINES, AND STANDING WAVES.

The study of antennas is essential to a complete understanding of radio communication and other electronic systems. In such systems, energy in the form of radio or electromagnetic waves is generated by electronic equipment and fed to an antenna by means of special transmission lines. The antenna radiates this energy at the speed of light. Receiving antennas placed in the path of the traveling wave, absorb part of this energy and send it to the receiving equipment by means of a transmission line.

The ability to obtain successful communication by means of radio waves depends chiefly on radio wave and the factors affecting its successful propagation.

Work Unit 3-1. FUNCTIONS OF AN ANTENNA AND ANTENNA RADIATION

STATE THE FUNCTION OF A TRANSMITTING ANTENNA.

STATE THE PURPOSE OF A RECEIVING ANTENNA.

STATE WHICH FIELD IS RADIATED BEYOND THE TRANSMITTING ANTENNA.

NAME THE TWO FIELDS/COMPONENTS WHICH MAKE UP THE RADIATION FIELD.

NAME THE FIELD WHICH IS FORMED FROM THE ELECTRIC AND MAGNETIC COMPONENTS OF THE RADIATION FIELD.

Functions of Antennas. The function of a transmitting antenna is to convert the ouptput power delivered by a radio transmitter into an electromagnetic field which radiates through space. Therefore, the transmitting antenna converts energy having one form to energy having another form. The receiving antenna makes the energy conversion in the opposite direction. The function of the receiving antenna is to convert the electromagnetic field that sweeps by it into energy that is delivered to a radio receiver. In transmitting, the antenna operators as the load for the transmitter; in receiving, it operates as the signal source for the receiver.

Antenna Radiation. When power is delivered to an antenna, two fields are set up by the fluctuating energy: one is the induction field which associates with the stored energy and the other is the radiation field which moves out into space at nearly the speed of light. At the antenna, the intensities of these fields are high and proportional to the amount of power delivered to the antenna. At a short distance from the antenna, and beyond, only the radiation field remains. This radiation field is composed of an electric component and a magnetic component.

The electric and magnetic fields (components) radiated from an antenna form the electromagnetic field, and this field is responsible for the transmission and reception of electromagnetic energy through free space. Thus, the radio wave may be described as a moving electromagnetic field having velocity in the direction of travel, and with components of electric intensity and magnetic intensity arranged at right angles to each other (fig 3-1).

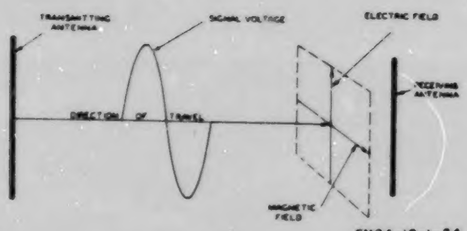


Fig 3-1. Components of electromagnetic waves.

Antenna Radiation Patterns. The energy of radio signals radiated by an antenna forms an electromagnetic field having a definite pattern, depending on the type of antenna used. This radiation pattern is used to show both range and directional characteristics of an antenna. A vertical antenna theoretically radiates energy equally in all directions. In practice, however, the pattern is usually distorted by nearby obstructions or terrain features.

The full or solid radiation pattern is a three-dimensional figure that looks somewhat like a doughnut, with a transmitting antenna in the center (fig 3-2). The top pattern in the figure is a quarter-wave vertical antenna and the bottom pattern is a half-wave horizontal antenna a 1/2-wavelength above the ground. The general method of illustrating a radiation pattern, however, is by cross-section of the full pattern showing only one particular plane (fig 3-3). The top pattern of the figure is a half-wave horizontal antenna a 1/4-wavelength above the ground and the bottom pattern is a half-wave horizontal antenna, 1/2-wavelength above the ground.

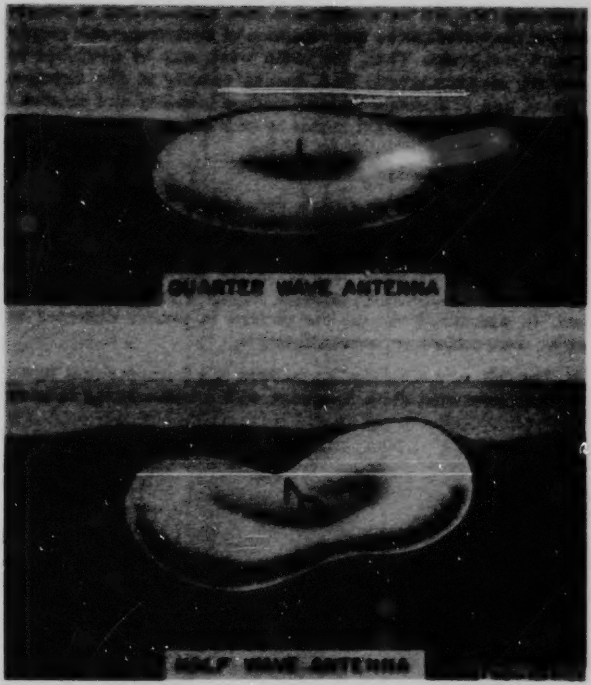

QUARTER WAVE ANTENNA
HALF WAVE ANTENNA

Fig 3-2. Solid radiation patterns from quarter-wave and half-wave antennas.

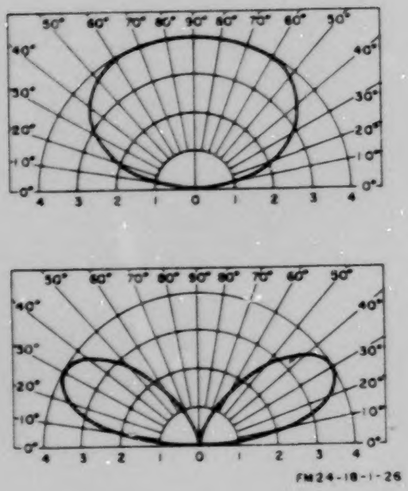


Fig 3-3. Cross-sectional representation of radiation pattern in one plane.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What is the function of a transmitting antenna?

2. What is the purpose of a receiving antenna?

3. Which of the two fields set up by fluctuating energy is radiated out into space?

4. The radiation field is composed of an ________________ component and a ________________ component.

5. The electric and magnetic fields (components) radiated from an antenna, form the ____________________ field.

Work Unit 3-2. ANTENNA POLARIZATION

STATE HOW THE POLARIZATION OF A RADIATED WAVE IS DETERMINED.

NAME THE TWO TYPES OF ANTENNA POLARIZATION.

STATE THE ANTENNA POLARIZATION TO BE USED WHEN WORKING WITH MEDIUM AND LOW FREQUENCIES.

STATE WHY IT'S BETTER TO USE HORIZONTALLY POLARIZED ANTENNAS AT HIGH FREQUENCIES.

STATE WHICH TYPE OF POLARIZATION TO BE USED AT VERY-HIGH AND ULTRA-HIGH FREQUENCIES.

GIVEN A LIST OF ADVANTAGES FOR THE VERTICAL AND HORIZONTAL POLARIZATION AND A LIST OF THE TYPES OF ANTENNA POLARIZATION, MATCH EACH ADVANTAGE WITH ITS APPROPRIATE ANTENNA POLARIZATION.

Polarization. Polarization of a radiated wave is determined by the direction of the lines of force making up the electric field. If the lines of electric force are at right angles to the surface of the earth, the wave is said to be vertically polarized (fig 3-4). If the lines of electric force are parallel to the surface of the earth, the wave is said to be horizontally polarized (fig 3-5).

A single-wire antenna is used to extract energy from a passing radio wave. Therefore maximum pickup results, if the antenna is so oriented, that it lies in the same direction as the electric-field component. Thus, a vertical antenna is used for efficient reception of vertically polarized waves and a horizontal antenna is used for the reception of horizontally polarized waves. In some cases, the field rotates as the wave travels through space. Under these conditions, both horizontal and vertical components of the field exist and the wave is said to have elliptical polarization.

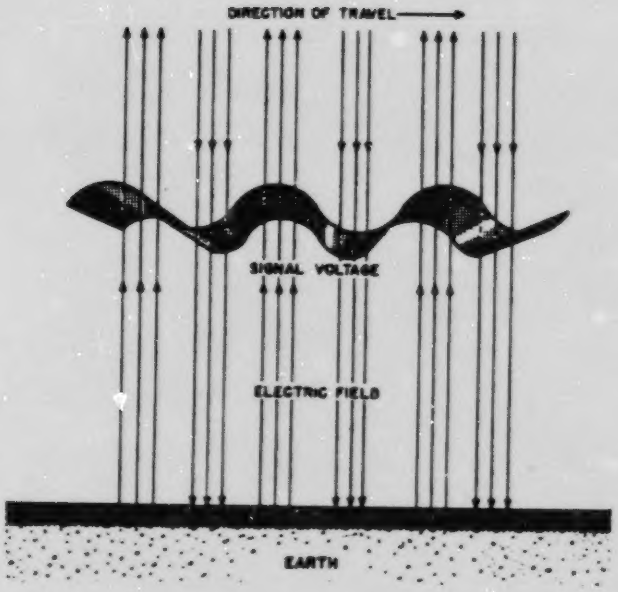


Fig 3-4. Vertically polarized signal.

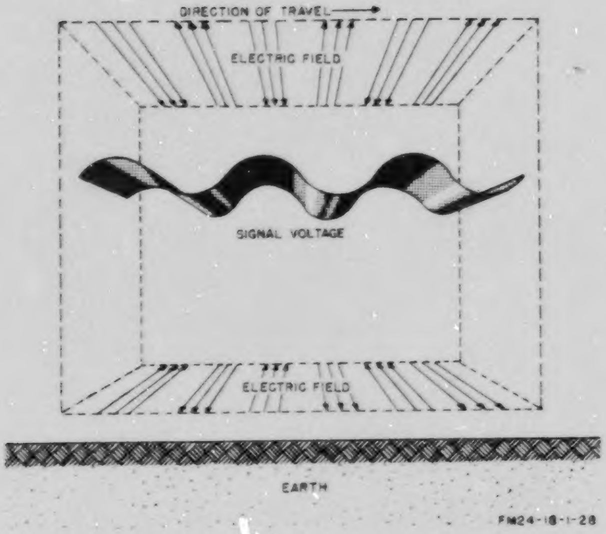


Fig 3-5. Horizontally polarized signal.

Polarization requirements for various frequencies. At medium and low frequencies, ground-wave transmission is used extensively, for this reason, it is necessary to use vertical polarization. Vertical lines of force are perpendicular to the ground, and the radio wave can travel a considerable distance along the ground surface with a minimum amount of attenuation (loss). Because the earth acts as a fairly good conductor at low frequencies, horizontal lines of force are shorted out and the useful range with horizontal polarization is limited.

At high frequencies with sky-wave transmission, it makes little difference whether horizontal or vertical polarization is used. The sky wave reflected by the ionosphere, arrives at the receiving antenna elliptically polarized. Therefore, the transmitting and receiving antennas can be mounted either horizontally or vertically. Horizontal antennas are preferred because they can be made to radiate effectively at high angles and have inherent directional properties.

With frequencies in the very-high or ultra-high range, either horizontal or vertical polarization is satisfactory. Since the radio wave travels directly from the transmitting antenna to the receiving antenna, the original polarization produced at the transmitting antenna is maintained throughout the travel of the wave to the receiving antenna. Therefore, if a horizontal half-wave antenna is used for transmitting, a horizontal antenna must be used for receiving. If a vertical half-wave antenna is used for transmitting, a vertical antenna must be used for receiving.

Advantages of Vertical Polarization. Simple, vertical half-wave antennas can be used to provide omni-directional communication which has the ability to communicate with a moving vehicle. When antenna heights are limited to 10 feet or less over land, as in vehicular installation, vertical polarization provides a stronger received signal at frequencies up to about 50 MHz. From approximately 50 to 100 MHz, there is only a slight improvement over horizontal polarization with antennas at the same height. The difference in signal strength above 1100 MHZ is negligible.

For transmission over sea water, vertical polarization is decidedly better than horizontal when antennas are below approximately 300 feet at 30 MHz. You would only need 50 feet at 85 MHz and still lower at the high frequency. Therefore, an ordinary antenna at mast heights, such as 40 feet, vertical polarization is advantageous for frequencies less than about 100 MHz.

Radiation using vertical polarization is less affected by reflections from aircraft flying over the transmission path. With horizontal polarization, such reflections cause variations in the received signal strength. This factor is important in locations where aircraft traffic is heavy.

With vertical polarization, less interference is produced or picked up because of strong VHF and UHF broadcast transmission and reception (television and frequency modulation), all of which use horizontal polarization. This factor is important when an antenna must be located in an urban area having several television and fm broadcast stations.

Advantages of Horizontal Polarization. A simple horizontal half-wave antenna is bi-directional. This characteristic is useful, if it is desired to minimize interference from certain directions.

Horizontal antennas are less apt to pick up man-made interference, polarized vertically.

When antennas are located near dense forest, horizontally polarized waves suffer lower losses than vertically polarized waves, especially above about 100 MHz.

Small changes in antenna location do not cause large variations in the field intensity of horizontally polarized waves when antennas are located among trees or buildings. When vertical polarization is used, a change of only a few feet in the antenna location may have a considerable effect on the received signal strength. This is the result of interference patterns which produce standing waves in space when spurious reflections from trees or buildings occur.

Since the interference patterns will vary even when the frequency is changed by only a small amount, considerable distortion may occur when complex types of modulation are used, as with television signals or with certain types of pulse-modulation systems. Under these conditions, horizontal polarization is preferred.

When simple half-wave antennas are used, the transmission line, usually vertical, is less affected by a horizontally mounted antenna. By keeping the antenna at right angles to the transmission line and using horizontal polarization, the line is kept out of the direct field of the antenna. As a result, the radiation pattern and electrical characteristics of the antenna are practically unaffected by the presence of the vertical transmission line.

Receiving Antennas. Vertical receiving antennas accept radio signals equally from all horizontal directions, just as vertical transmitting antennas radiate equally in all horizontal directions. Because of this characteristic, other stations operating on the same or adjacent frequencies may interfere with the desired signal and make reception difficult or impossible. However, reception of a desired signal can be improved by using directional antennas.

Horizontal half-wave antennas accept radio signals from all directions other than the two directions in direct line with the ends of the antenna. Thus, when only one signal is causing interference, or when several interfering signals are coming from the same direction, interference can be eliminated or reduced by changing the antenna installation so that either end of the antenna points directly at the interfering station.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. How is the polarization of a radiated wave determined?

2. What are the two types of antenna polarization?

   a. ______

   b. ______

3. What kind of antenna polarization should you use when working with low and medium frequencies?

4. Why is it better to use horizontally polarized antennas at high frequencies?

5. Which type(s) of polarization should be used at very-high and ultra-high frequencies?

Matching: Column 1 (6 through 9) lists advantages of vertical and horizontal polarization. Column 2 (a and b) lists the two types of antenna polarization. Match the specific advantage in column 1 with that type of polarization which provides the advantage in column 2. Write your answers in the spaces provided.

Column 1	Column 2
Advantages of vertical and horizontal polarization	Types of antenna polarization
____ 6. Useful in minimizing interference from certain directions	a. Vertical
____ 7. Useful when communicating with moving vehicles	b. Horizontal
____ 8. Is somehwhat less affected by aircraft flying over the transmission path	
____ 9. Suffers lower losses when located near dense forests	

Work Unit 3-3. CONVENTIONAL FIELD ANTENNAS

DESCRIBE ANTENNA EQUIPMENT RC-292.

DESCRIBE ANTENNA AS-2851/TR.

STATE WHICH ANTENNA SYSTEM CONSIST OF A COLLAPSIBLE FOLDING LOG PERIODIC ANTENNA SHAPED IN THE FORM OF A SQUARE.

STATE WHICH ANTENNA SYSTEM IS DESIGNED TO PROVIDE SHORT-RANGE SKY-WAVE PROPAGATION.

Antenna Equipment RC-292 (fig 3-6) is an elevated, wide band, modified ground plane antenna designed to operate with and increase the operating range (FM radios 50 to 200 percent) of various radio sets. The antenna is a vertical radiating element. Three ground plane elements are installed at a 142° angle to the antenna (vertical element) to act as a counterpoise (artificial ground). The lengths of the elements can be preadjusted for best performance with each type of radio. The antenna is elevated on a 30-foot sectional mast, increasing the line-of-sight distance to the horizon. It is held in place by guy ropes and ground stakes and is connected to the radio by a 58-foot 50-ohm coaxial cable. This antenna equipment is designed for hand or vehicular transportation, and when disassembled is packed in a canvas roll (CW-50/TRC-7).

The antenna requires no tuning in operation and provides a radiation pattern that is omni-directional in the horizontal plane. However, the lengths of the antenna elements must be preadjusted for the different frequency ranges of the radio set with which it is being used. This is done by changing the number of mast sections in the antennas and ground plane elements. The swivel ground stake on which the mast is supported makes it easy to lower the antenna and make the necessary changes. The RC-292's overall frequency range is from 20-75.95 MHz. It can be erected by two men in approximately 15 minutes. Its maximum height is 41 1/2 ft and minimum height is 37 ft. Its total weight including spares is 48 lbs. For more information on the RC-292, see TM 11-5820-348-15 or MCI correspondence course number 25.30, VHF Field Radio Equipment.

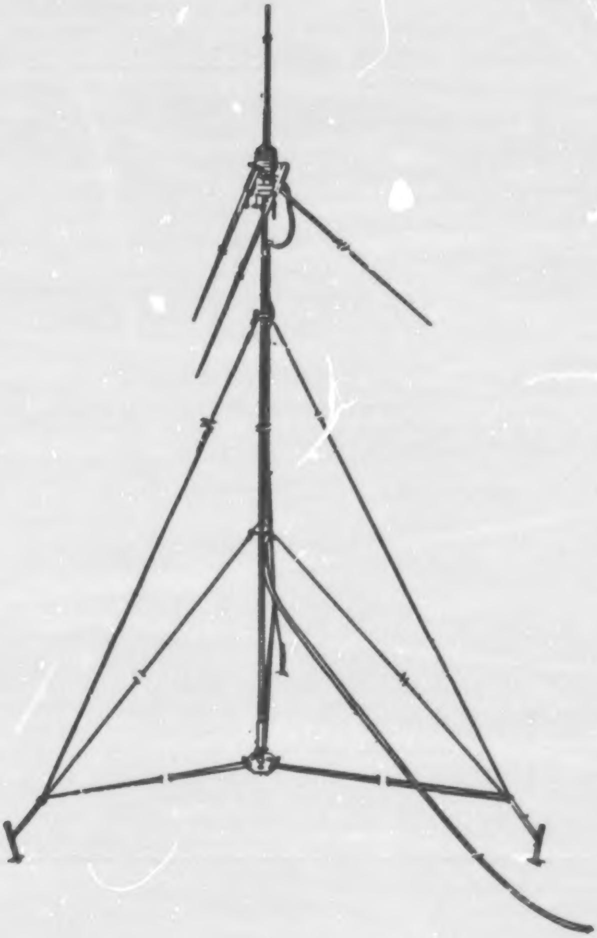


Fig 3-6. Antenna equipment RC-292.

Antenna AS-2851/TR

Description, Physical and Functional. The Antenna AS-2851/TR (fig 3-7) is a man-transportable tactical log periodic antenna which provides transmission and reception capabilities over the 30 to 76 MHz frequency range. It can be assembled or disassembled by two men in less than 10 minutes. See table 3-1 for reference data.

Table 3-1. Reference Data

Power Handling Capability	65 watts average 135 PEP
Frequency Range	30 to 76 MHz
Input Impedance	50 ohms unbalanced
VSWR	2 to 1 maximum
Forward Gain	4dbi 30 to 35 MHz
	4.5dbi 35 to 76 MHz
Front to Back Ratio	4db at 30 MHz
	7.5db at 50 MHz
	10db at 76 MHz
Overall Height	20 feet
Operating Temperature Range	-60° to 150°F
Humidity Limits	to 95%
Maximum Wind Survival	60 knots no ice
Longest Element Tip to Tip	16'-8"
Boom Length	6'-0"
Weight	Approx. 30 lb.
Polarization	Vertical or Horizontal

a. Physical Description. The following paragraphs describe the major components of the AS-2851/TR.

(1) Antenna Array Assembly. The antenna array assembly consists of a folding boom which supports a planar array of seven log periodic dipole elements. When collapsed and folded for storage, the antenna array assembly fits into a 48-inch-long by 8-inch-wide space. A polarization block and polarization change rope permit the polarization of the antenna to be changed without lowering or disassembling the mast.

(2) Mast Assembly. The mast assembly consists of six separate mast sections which support the antenna array assembly at its fully extended height of 20 feet. The upper metal mast section contains a collar bearing for attachment of the guy cable assembly. The upper two mast sections are constructed of fiberglass to prevent distortion of the antenna radiation pattern.

(3) Mast Base Assembly. The mast base assembly consists of a metal plate with a hinged mast base clamp to permit the mast to be assembled horizontally and tilted up into position. Two wing nuts on the base clamp permit azimuth adjustment. A metal tab is provided for attachment of the polarization change rope.

(4) Guy Ring Assembly. This assembly consists of a guy ring, three dielectric rope guy lines and tensioning devices of sufficient strength to hold the antenna upright in a 60-knot wind.

(5) Antenna Guy Hold-downs. Five metal spike-shaped stakes, approximately 9 inches long, are provided to anchor the base plate and three guy lines.

(6) Hammer. A small machinist's type hammer with approximately 1-pound head weight is provided.

(7) Cable Assembly. The cable assembly consists of 75 feet of RG-58C/U coaxial cable terminated with UG-88 B/U connectors on each end. A strain relief snap on the upper end of the cable attaches to the antenna boom to eliminate strain on the connector caused by the weight of the dangling cable.

(8) Antenna Case. All components of the AS-2851/TR are packed in a rollout type canvas case with straps to position components securely. A weatherproof pictorial operating and assembly instruction plate is affixed to the inside of the case.

b. Functional Description. This antenna is employed as a directional, lightweight, man-transportable antenna for use with tactical VHF FM radio equipment. It is a component of the Radio Terminal Set AN/TRC-166.

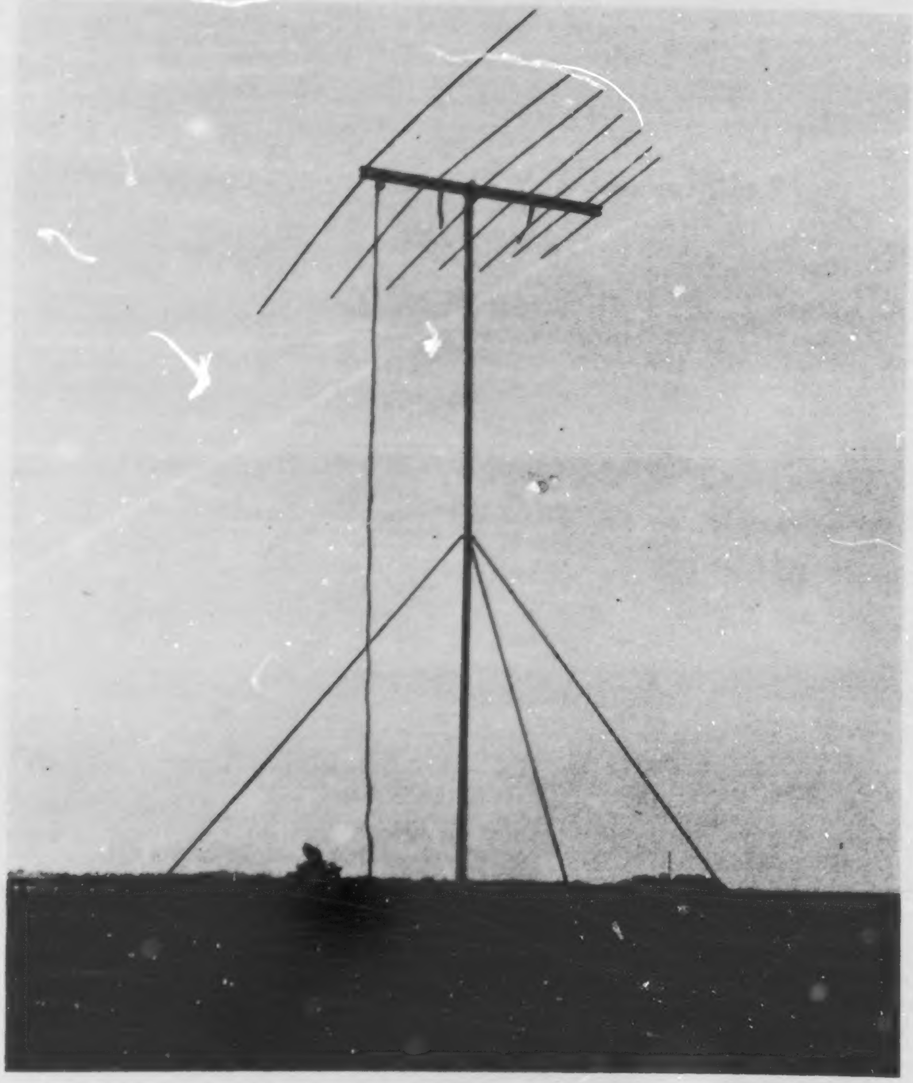


Fig 3-7. Overall view of AS-2851/TR antenna system.

For more information on the AS-2851/TR, see TM-07505A-14 or MCI correspondence course number 25.31, VHF Multichannel Radio Equipment.

Antenna System AS-2236/GRC

The AS-2236/GRC Antenna System (fig 3-8) is a portable, easily assembled unit which provides transmission and reception capabilities over the 30 MHz to 76 MHz frequency range. The system consists of a collapsible folding log periodic antenna shaped in the form of a square, an RG-8A/U 53 ohm RF cable assembly, a tripod assembly, six metallic mast sections, two dielectric mast sections, a guying assembly, nine stakes, and a hammer, packaged in three separate canvas carrying bags. Assembly of the system is accomplished by two men in less than 10 minutes under variable terrain and soil conditions. Built primarily for point to point communication, the antenna receives maximum strength signals at its front while signals received at the sides or the back are diminished. This directional characteristic is used to increase signal strength of a desired station while reducing signal stength of possible interfering stations. Azimuth direction of the antenna may be changed without moving the tripod legs or guy lines. In addition, the antenna may be mounted on the mast in either the horizontal or the vertical position, thereby providing a choice of polarization.

Table 3-2. The Reference Data for the Antenna System AS-2236/GRC

Packaging Dimensions	Three packs, each 48 inches long Max.
System Weight	Three packs, each 35 pounds Max.
Erected Height	35-feet Max.
Assembly Time	Ten minutes Max. (two men).
Max. Wind Speed	60 knots (guy lines secured and tensioned).
Frequency Range	30 MHz to 76 MHz
Polarization	Vertical or Horizontal
Max. Power	65 watts CW.

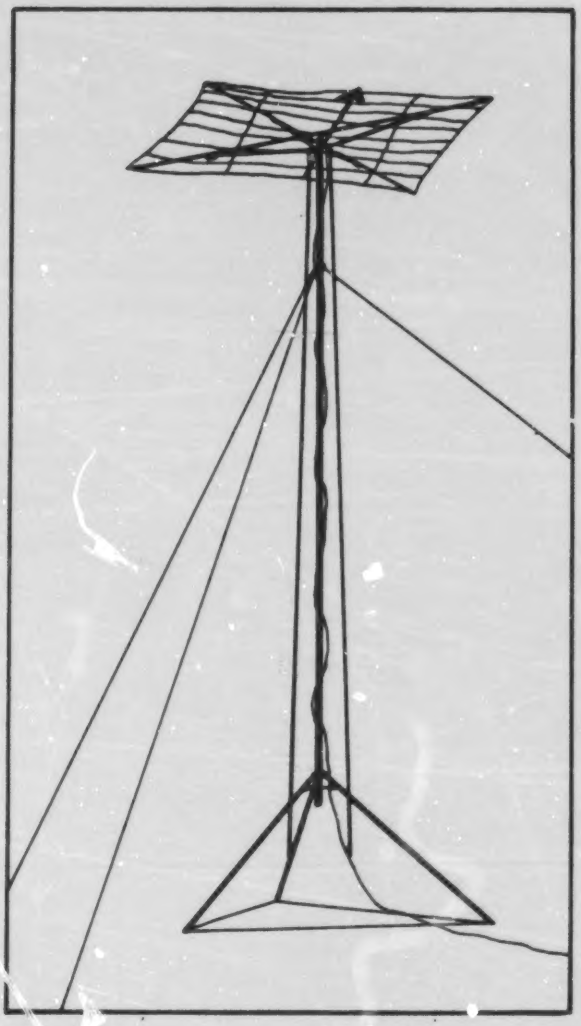


Fig 3-8. The AS-2236/GRC antenna system.

For more information on the Antenna System AS-2236/GRC, see TM-06728A-15 or MCI correspondence course number 25.31, VHF Multichannel Radio Equipment.

Antenna AS-2259/GR

The AS-2259/GR Manpack HF Antenna (fig 3-9) is essentially a dipole antenna fed with a low-loss, foam-dielectric, coaxial mast that also serves as a support structure. The dipole system uses a set of crossed sloping dipoles positioned at right angles to each other. Physically the antenna consists of eight lightweight coaxial mast sections and four radiating elements that also serve as guys. The antenna is transported in a canvas pack similar to a tool roll. The total packed weight of the antenna is 14.7 pounds. Erection is accomplished by two men in 5 minutes without the use of any tools.

The AS-2259/GR antenna is designed to provide high-angle radiation (near vertical incidence) to permit short-range skywave propagation over communication circuits varying from 0 to 300 miles. The AS-2259/GR may be used with tactical HF radios that tune a 15-foot whip antenna, such as the AN/PRC-47. The frequency range of the antenna is 2.0 to 30.0 MHz and maximum RF power capacity is 1000 watts pep, or average.

Leading particulars and summary of equipment for the AS-2259/GR are listed in tables 3-3 and 3-4. Personnel should become thoroughly familiar with data and procedures contained in the entire instruction manual before working on or using the antenna.

For more information on the Antenna AS-2259/GR, see TM-07508A-14 or MCI correspondence course number 25.32, HF/UHF Field Radio Equipment.

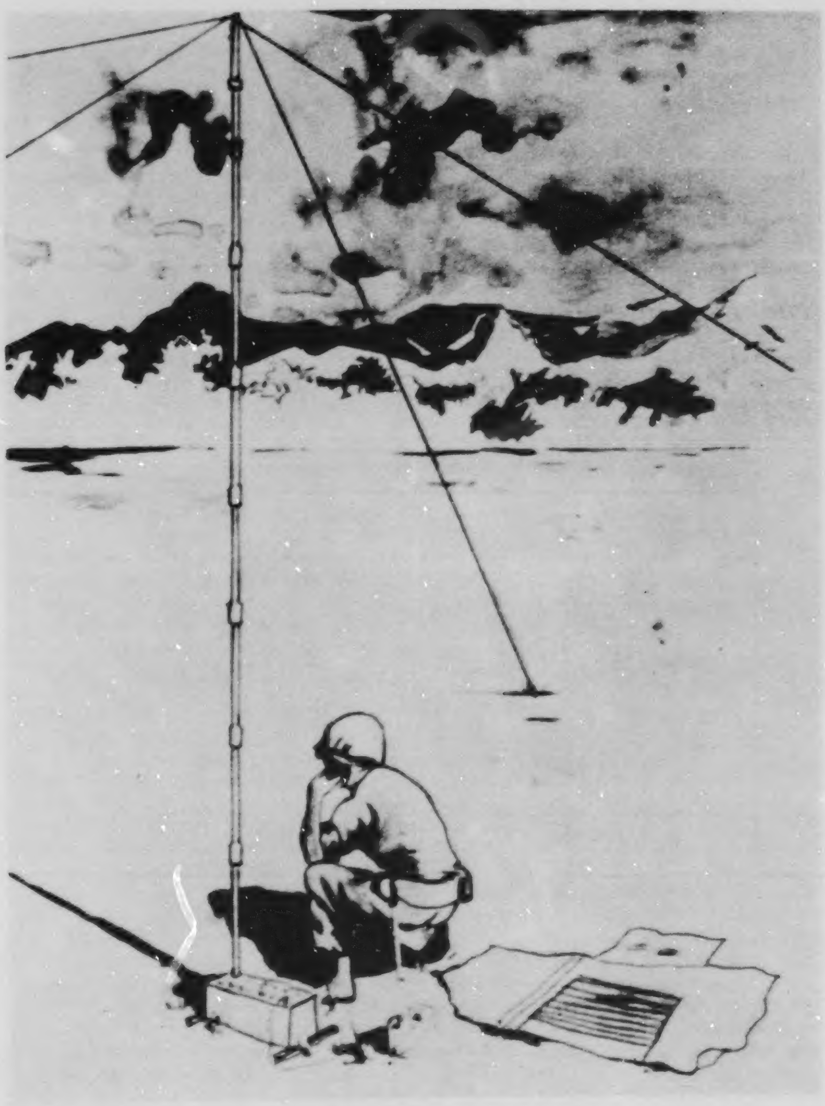


Fig 3-9. AS-2259/GR manpack HF antenna.

Table 3-3. Leading Particulars

ITEM	LEADING PARTICULARS
Electrical Characteristics:	
Frequency range	2.0 to 30.0 MHz
Polarization	Horizontal and vertical simultaneously.
RF power capacity	1000 watts pep or average.
Input impedance	Compatible with output of radios using 15-foot whips, such as the AN/PRC-47.
Radiation pattern	
Azimuth	Omnidirectional.
Elevation	Near vertical incidence.
Gain:	Similar to a dipole mounted horizontally, 10 feet above same type ground.
Physical Characteristics	
Wind and ice	Survives 60 mph wind with no ice.
Height erected	15 feet.
Land area required	60 by 60 feet.
Erection time	Two men, 5 minutes; one man 15 minutes.
Packed weight	Less than 14.7 pounds.

Table 3-4. Summary of Equipment

MILITARY TYPE NO.	DESCRIPTION OF EQUIPMENT
AS-2259/GR	An antenna which may be used directly with HF manpack radios that tune a 15-foot whip antenna, such as the AN/PRC-47. The antenna is rated at 1000 watts pep or average RF power.
MX-9313/GR	An adapter fitting for mounting the antenna on vehicles or shelters equipped with HF radios. Adapts Antenna AS-2259/GR to the AN/TRC-75, AN/MRC-83, AN/MRC-87, AN/TSC-15, and similar radios employing 1-inch 8 threads per inch whip bases and automatic couplers.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Describe antenna equipment RC-292. ______________________________

____

2. Describe antenna AS-2851/TR.

____

3. Which antenna system consists of a collapsible folding log periodic antenna shaped in the form of a square?

____

4. Which antenna system is designed to provide short-range skywave propagation?

____

Work Unit 3-4. FIELD EXPEDIENT ANTENNAS

GIVEN A LIST OF THE VARIOUS FIELD EXPEDIENT ANTENNAS WITH ILLUSTRATIONS, MATCH EACH ANTENNA WITH THE APPROPRIATE ILLUSTRATION.

STATE HOW THE LONG WIRE ANTENNA'S BEST PERFORMANCE IS OBTAINED.

STATE WHAT HAPPENS TO A HALF-RHOMBIC ANTENNA WHEN TERMINATED IN A RESISTOR.

STATE THE LENGTH FOR WHICH THE VERTICAL AND GROUND PLANE ELEMENTS FOR AN EXPEDIENT GROUND PLANE ANTENNA SHOULD BE CUT.

Half-Wave Dipole

The half-wave dipole antenna (fig 3-10) consists of two conductors, each a quarter-wavelength separated in the middle by an insulator. The feed lines are connected to the two separated conductors. The antenna is then supported along a straight line by means of ropes tied to either end of the antenna along with supporting structures such as buildings, trees, poles, etc. Current is maximum at the center and minimum at the ends. Voltage is maximum at the ends and minimum at the center.

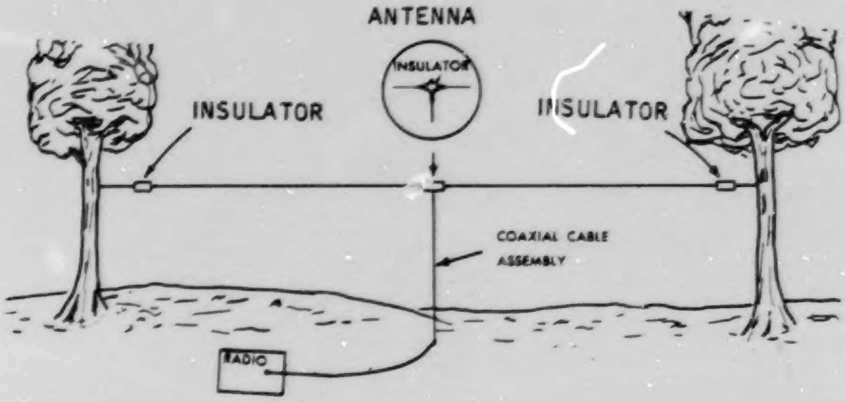


Fig 3-10. Horizontal dipole.

The half-wave dipole antenna can be mounted in either a vertical, horizontal or slanting position. Its radiation pattern is pictured in figure 3-11, where the antenna shown is positioned vertically. Maximum radiation is perpendicular to the antenna axis. Since there is no radiation from the ends of the antenna, for this reason, a figure-8 pattern is present in the vertical plane. Thus, the antenna is bi-directional in the vertical plane. As shown, radiation is constant in any direction in the horizontal plane. Mounting the antenna horizontally would reverse the pattern illustrated in figure 3-11.

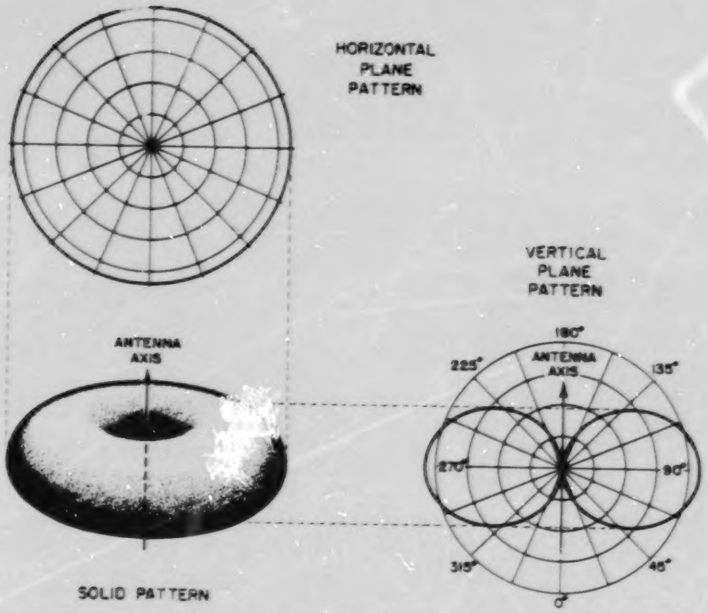

HORIZONTAL PLANE PATTERN
VERTICAL PLANE PATTERN
180°
225°
135°
ANTENNA AXIS
270°
90°
315°
45°
0°
ANTENNA AXIS
SOLID PATTERN

Fig 3-11. Radiation pattern of a dipole (half-wave) antenna.

Formula for actual construction is shown in appendix I.

Two-Element Yagi

This configuration may be new to most communicators. As seen in figure 3-12, it consists of a reflecting element (a single wire) mounted 1/4-wavelength behind a dipole antenna. This addition will substantially increase the gain and make the antenna more directional.

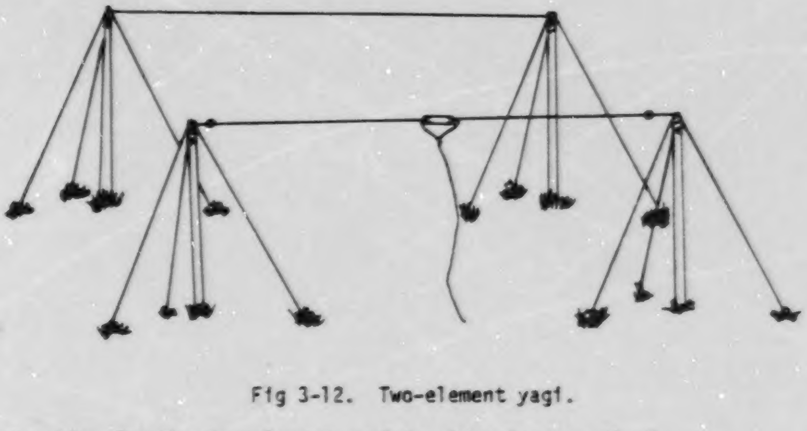


Fig 3-12. Two-element yagi.

Construction for the two element yagi is shown in appendix I.

Long Wire Antenna

Long wire antennas (fig 3-13) are long single wires supended 1/2-wavelength above the ground and consist of an order of 2-6 wavelengths long. Long wire antennas have two basic advantages over other antennas. These advantages are increased gain and directivity.

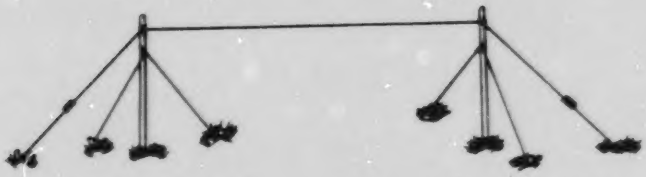


Fig 3-13. Long wire antennas.

Best performance is obtained by directing a major lobe towards the intended receiver (fig 3-14).

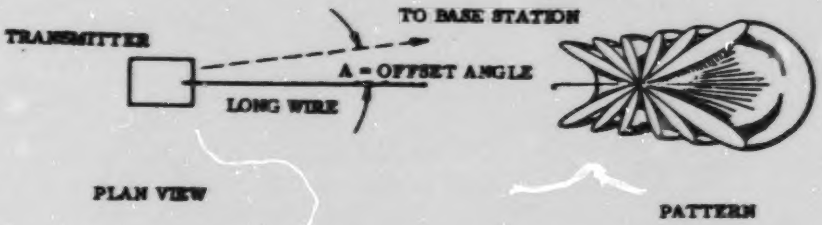

TRANSMITTER
TO BASE STATION
A = OFFSET ANGLE
LONG WIRE
PLAN VIEW
PATTERN

Fig 3-14. Radiation pattern of the long wire antenna.

This is easily accomplished by aligning the antenna with an azimuth to the outstation and adding or subtracting the wave angle (fig 3-14). A different wave angle is associated with each length of antenna (table 3-5).

Table 3-5. Offset Angle (A) Long Wire Antennas

	WIRE LENGTH (L) (Meters)					Height (H) (Meters)
Freq-(MHz)	10	20	40	80	150	
10			43°	27°	16°	30.0
12		55°	38°	23°	13°	25.0
14		51°	35°	21°		21.4
16		49°	31°	19°		18.7
18		47°	29°	17°		16.7
20		43°	27°	16°		15.0
24	55°	38°	23°			12.5
30	50°	33°	20°			10.0

Because of its high gain and the low elevation angle of its main radiation lobe, the long horizontal wire antenna is one of the simplest antennas to erect.

The long wire antenna is capable of spanning distances in excess of 100 km and is one of the most practical antennas for use against jamming. The long wire antenna is bi-directional to uni-directional construction of the long wire antenna is shown in appendix I.

Half-rhombic Antenna

The half-rhombic antenna (fig 3-15) is a terminated vertical antenna which resembles a obtuse-angle V antenna. With the half-rhombic antenna, an unbalanced transmission line and a ground or counterpoise is used. As a result, a vertically polarized radio wave is produced and the antenna is bi-directional. The antenna can be made to be uni-directional by connecting a resistor of about 500 ohms between the far end of the antenna and the ground.

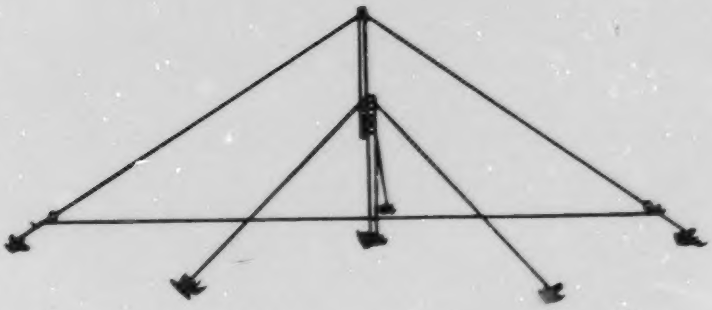


Fig 3-15. Half-rhombic antenna.

The typical military half-rhombic antenna consists of a 100-foot antenna wire erected over a single 30-foot wooden mast and an 85-foot counterpoise wire placed under the antenna about one foot off the ground and attached to both ends of the antenna. See appendix I for construction.

Sloping V Antenna

The sloping V antenna (fig 3-16) consists of downward sloping long wires arranged to form a "V" and is fed with current of opposite polarity. Major lobes from each wire combine in such a way that maximum radiation occurs in the direction of a lobe that bisects the angle of the legs. The pattern is basically bi-directional along the lines bisecting the angle, producing primarily shy waves.

The greater the leg length, the greater effect of gain and directivity of the antenna. The gain (increase in effective power or performance) of a "V" antenna is almost double that of a single long wire, since the radiation from the lobes of two waves (legs) combine.

For maximum use of a "V" antenna, the legs should be cut to three wave lengths at the center frequency of the desired band with an apex angle of 55 degrees. The antenna can be made more directional by terminating the individual legs with a non-inductive resistor of about 500 ohms. See appendix I for construction.

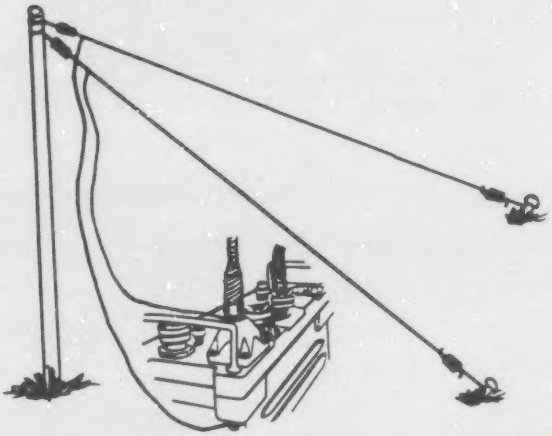


Fig 3-16. Sloping "V" antenna.

Vertical 1/4-wave whip antenna

The vertical whip antenna is the most widely used omni-directional antenna found in the military. The tactical communicator is most familiar with the whip antenna used on vehicles, and the ground plane antenna which is usually mounted on masts or other structures.

The expedient vertical 1/4-wave whip antenna (fig 3-17) is a single bare or insulated wire held vertically by a means of support and connected to the antenna connector on the face of the radio. The vertical whip is omni-(all) directional, and its efficiency is related to the transmitting frequency and antenna height. At lower frequency, its efficiency is very low, but as the frequency increases its efficiency also increases. Antenna height can be helped by placing the antenna on top of a hill or by fastening it to a pole or tree to increase its height above surrounding terrain or structures.

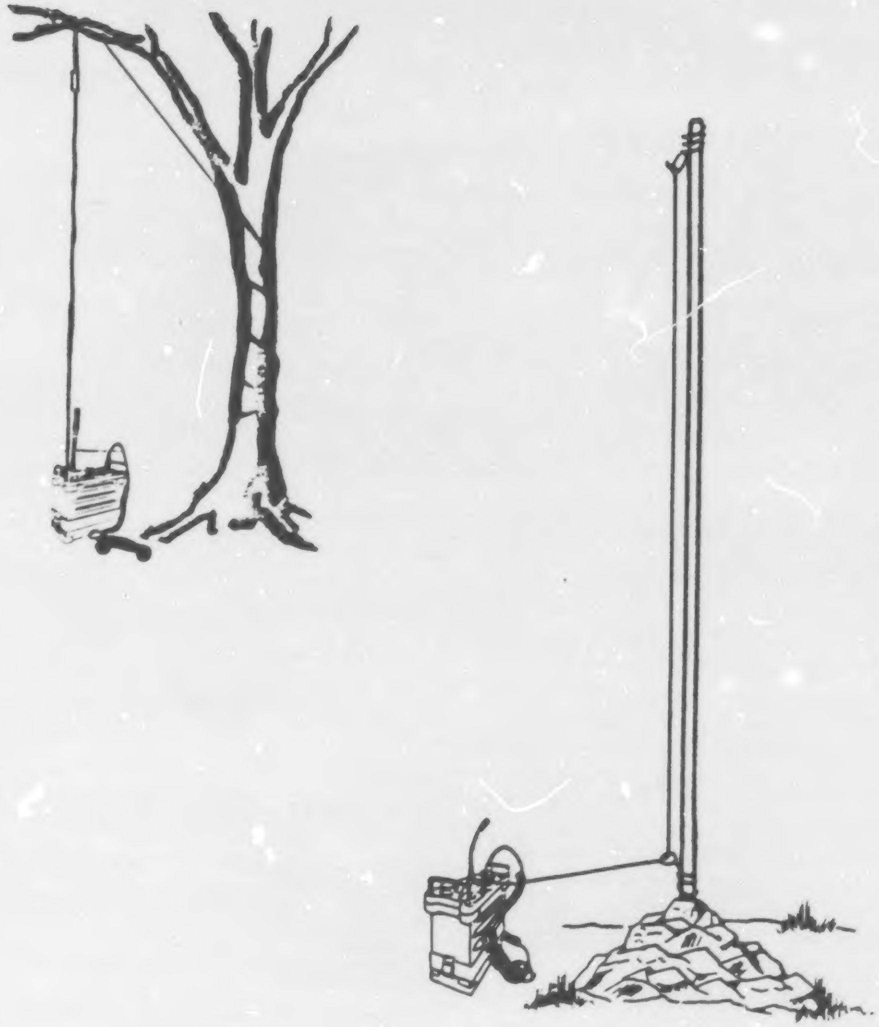


Fig 3-17. Vertical 1/4-wave whip antenna.

See appendix I for construction examples.

Field Expedient Ground Plane Antennas

Field expedient versions of the issue RC-292 operates at frequencies above 20 MHz. They are either pole supported or tree hung (fig 3-18). Their radiation pattern is omni-directional. The vertical and ground plane elements are cut for a 1/4-wave, the ground plane elements should be at 45-degree angles. Insulators are used to separate vertical elements from the ground plane elements.

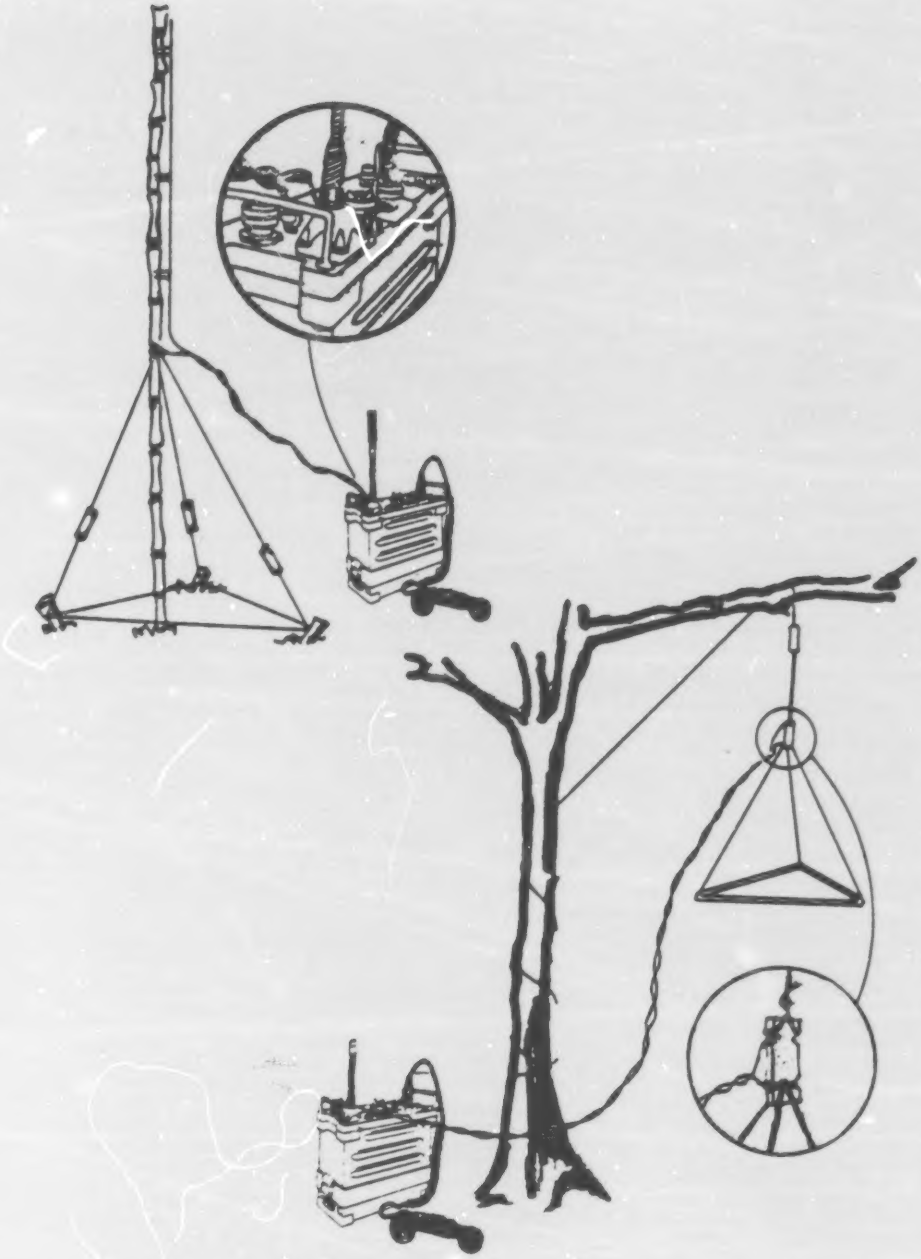


Fig 3-18. Field expedient ground plane antennas.

See appendix I for construction example.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

Matching: From the following illustrations (a through g), match the various field expedient antennas. Place the correct letter of the illustration in the spaces provided.

Column 1

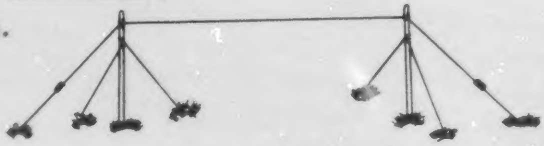
Field expedient antennas

____1. Half-wave dipole
____2. Lone Wire
____3. Sloping V
____4. Vertical 1/4-wave whip
____5. Two-element yagi
____6. Half rhombic
____7. Ground plane

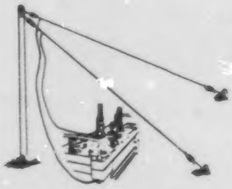
Column 2

Illustrations

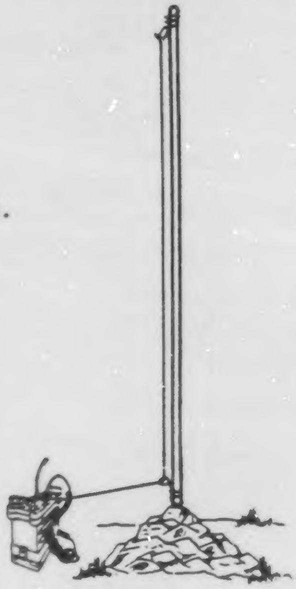
a.



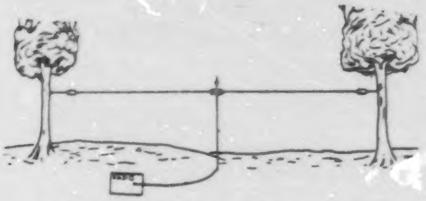
b.



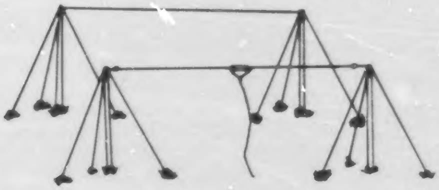
c.



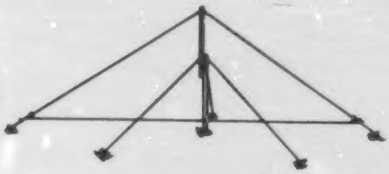
d.



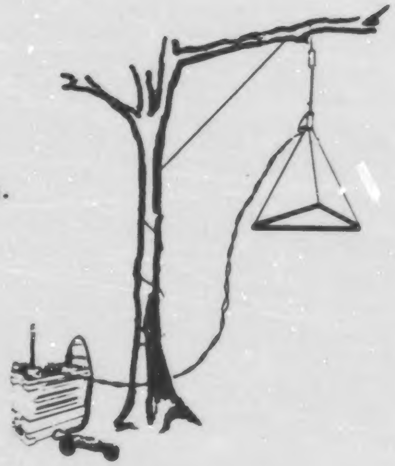
e.



f.



g.



8. How can the long wire antenna best performance be obtained?

____

____

9. What happens to a half-rhombic antenna terminated in a resistor?

____

____

____

10. What length should the vertical and ground plane elements for an expedient ground plane antenna be cut? ______________________________

Work Unit 3-5. TRANSMISSION LINES

DEFINE TRANSMISSION LINE.

DESCRIBE STANDING WAVES.

GIVEN THE TYPES OF TRANSMISSIONS, MATCH EACH TRANSMISSION WITH THE APPROPRIATE ILLUSTRATION.

STATE THE ADVANTAGES IN USING A TWISTED PAIR TRANSMISSION LINE.

STATE ONE DISADVANTAGE IN USING A TWISTED PAIR TRANSMISSION LINE.

STATE ONE ADVANTAGE IN USING A SHIELDED PAIR TRANSMISSION LINE.

Transmission Lines

A transmission line is a conductor that transfers radio frequency (RF) energy from the transmitter to the antenna or from the antenna to the receiver.

Transmission lines fall into two main categories: balanced and unbalanced lines. The terms balanced and unbalanced describe the relationship between transmission line conductors and the earth. The balanced line is composed of two identical conductors, usually circular wires, separated by air or an insulating material. The voltage between each conductor and ground, produced by an RF wave as it moves down a balanced line, are equal and opposite; i.e., at the moment one of the conductors supports a positive voltage with respect to ground, the other supports a negative voltage of equal magnitude. Some balanced transmission lines carry a third conductor; sometimes in the form of a braided shield which acts as a ground. Unbalanced lines are usually seen in the form of an open single wire line or coaxial cable. The unbalanced line can be imagined as just one half of a balanced line. Example of balanced and unbalanced lines are shown in figure 3-19.

Standing Waves

A standing wave is a motionless wave on an antenna accomplished by an impedance mismatch. When an impedance mismatch occurs in an antenna system, voltage and current is reflected back down the transmission line to the transmitter. This causes a power loss and results in poor antenna efficiency.

Circuits that contain capacitance or inductance and operate at some frequency have impedance (impedance describes the nature and size of whatever impedes the flow of current and wave). Impedance like resistance uses ohms as its unit of measure but cannot be measured with an ordinary ohmmeter.

The impedance of an antenna at the point where the lead-in (called a feed line or transmission line) is attached is called the antenna input impedance. For maximum efficiency, an antenna must be the proper length for the frequency at which it operates. Just as important, the characteristic impedance or impedance of the transmission line and the antenna input impedance must match. If a mismatch occurs anywhere in the antenna system, standing waves will result. Equally important as the impedance of the feed line matching the antenna, the output impedance of the transmitter must also match the impedance of the feedline.

Most military transmitters provide 50-ohm impedance at the antenna output. Most expedient half-wave antennas have approximately 70-ohm impedance. By matching the transmission line to the transmitter with a 50-ohm line, we have a 20-ohm difference at the antenna, or by matching the transmission line to the antenna with a 70-ohm line we would have a 20-ohm difference at the transmitter. The mismatch at the transmitter end or the antenna end, produces what we refer to as a standing wave ratio (SWR). With a 70-ohm to 50-ohm ration, we find that we have a 1.4 to 1 SWR (this is found by dividing 70.0 ohms by 50 ohms). With our HF equipment, it is recommended that you DO NOT operate a system with a mismatch, or SWR greater than 1.5 to 1.

Types of transmission lines

(1) Parallel two-wire line. The parallel two-wire line (fig 3-20) consists of two parallel conductors separated by insulators or spreaders at various intervals. It is available in two types: spreader bar and twin lead. The spreader bar type uses ceramic or polystyrene bars as spacers between the two conductors. The impedance for this type of line is from 50-700 ohms. The twin lead consists of two conductors that are molded into a low-loss polyethylene plastic. It's available in impedances ranging from 75 to 300 ohms.

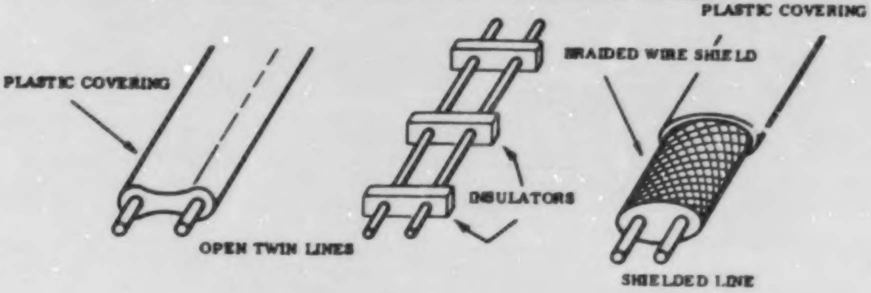
(2) Twisted pair. The twisted pair transmission line (fig 3-20) consists of two insulated conductors twisted together. Two features of the twisting are: holding the line together and cancelling out the effects of nearby magnetic/electric fields. The impedance is generally 70 to 100 ohms. The advantages to this type of line are ease of construction and readily accessible material. The disadvantages of the twisted pair transmission lines are: some RF loss in transmission line power, extreme care must be taken when using this type of transmission line with of HF or high powered equipment in order to prevent shock hazard and to ensure that the wire used is capable of handling the transmitter power, and the impedance difference between the transmitter and the line at 20 to 50 ohms.

(3) Shielded pair transmission line. The shielded pair (fig 3-20) consists of two conductors separated and surrounded by insulation material. The insulation material is then covered with a flexible copper braid that acts as a shield. The shield is then coated with rubber or a similar material to protect it against moisture and friction. Because of the shield, the line is not affected by nearby electric or magnetic fields. The advantages of shielded pair transmission lines are: the conductors balanced to ground and the capacitance between the cable is uniform throughout the length of the line. This balance is due to the grounded shield that surrounds the conductor with a uniform spacing along the entire length. The copper braid shield isolates the conductors from stray magnetic fields.

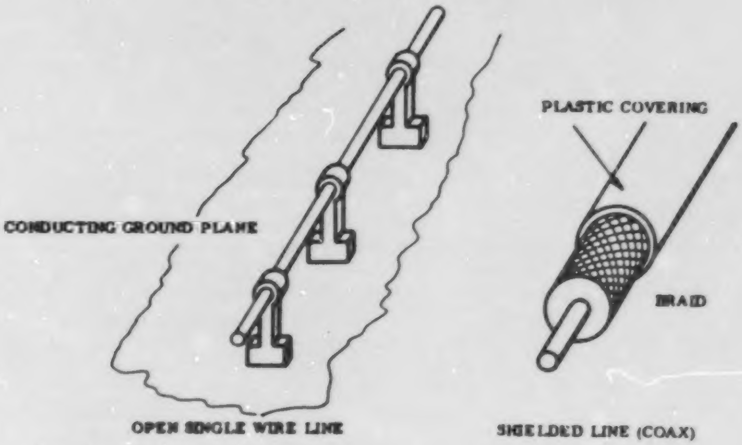
(4) Coaxial transmission lines. The coaxial transmission line (fig 3-20) consists of two conductors, one of which is hollow. The other is centered inside the hollow conductor to provide uniform characteristics throughout the cable. The center conductor is surrounded by a polyethylene plastic. The outer conductor is a flexible copper braid. This type of cable has extremely low losses at high frequencies; it is very desirable for communication application. The advantages of the coaxial cable are: ease of construction, readily accessible material, minimal shock hazard if constructed properly, it is waterproof and has minimal RF loss at operating frequency. The disadvantage is the cost of the cable.

Table 3-6. Types of Coaxial Transmission Line

RG-8/u	53ohm - 2kw
RG-58/u	53ohm - 430w
RG-213/u	53ohm - 2kw
RG-59/u	73ohm - 680w
RG-11/u	75ohm - 1.4kw

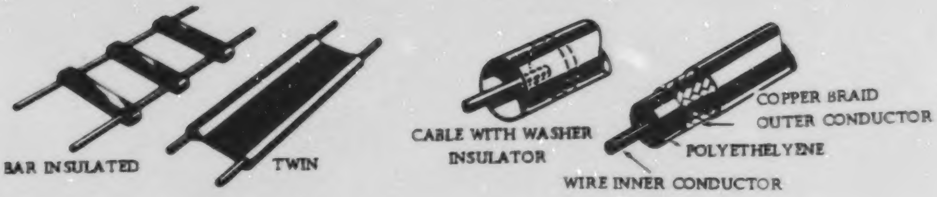


BALANCED TRANSMISSION LINES



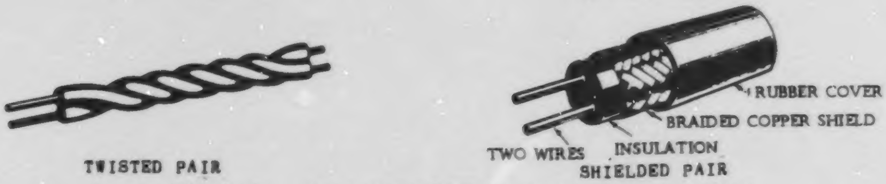
UNBALANCED TRANSMISSION LINE

Fig 3-19. Balanced and unbalanced transmission lines.


BAR INSULATED
TWIN
CABLE WITH WASHER INSULATOR
COPPER BRAID OUTER CONDUCTOR
POLYETHELYENE
WIRE INNER CONDUCTOR

PARALLEL TWO-WIRE

COAXIAL CABLE


RUBBER COVER
BRAIDED COPPER SHIELD
TWO WIRES
INSULATION

TWISTED PAIR

SHIELDED PAIR

Fig 3-20. Four general types of transmission line.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Define transmission line.

2. What are standing waves?

Matching: From the following illustrations (a through d), match the four types of transmission lines. Place the correct letter of the illustration in the spaces provided.

Column 1

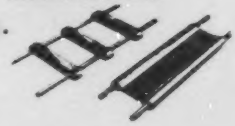
Types of transmissions

____ 3. Shielded pair
____ 4. Twisted pair
____ 5. Parallel two-wire
____ 6. Coaxial cable

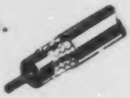
Column 2

Illustrations

a.



b.



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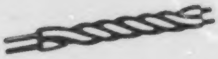
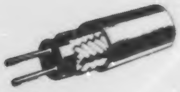


d.



7. What are the advantages in using a twisted pair transmission line?

8. One disadvantage in using a twisted pair transmission line is

____

____

____.

9. One advantage in using a shielded pair transmission line is

____

____

____

____.

SUMMARY REVIEW

In this study unit, you have learned about the functions of an antenna. You have learned about antenna polarization, the polarization requirements of various frequencies and about the conventional field antennas used within the Marine Corps. You have also learned several types of field expedient antennas and several types of transmission lines that can be used to feed these antennas.

Answers to Study Unit #3 Exercises

Work Unit 3-1.

1. To convert the output power delivered by a radio transmitter into an electromagnetic field that is radiated through space
2. To convert the electromagnetic field that sweeps by it into energy that is delivered to a radio receiver
3. Radiation field
4. electric, magnetic
5. electromagnetic

Work Unit 3-2.

1. By the direction of the lines of force making up the electric field
2. a. Vertical
   b. Horizontal
3. Vertical
4. They can be made to radiate effectively at high angles and have inherent directional properties
5. Vertical or horizontal
6. b
7. a
8. a
9. b

Work Unit 3-3.

1. An elevated, wide band, modified ground plane antenna
2. A man-transportable tactical log periodic antenna
3. AS-2236/GRC
4. AS-2259/GR

Work Unit 3-4.

1. d
2. a
3. b
4. c
5. e
6. f
7. g
8. By directing a major lobe towards the intended receiver
9. Its becomes uni-directional
10. One quarter (1/4) wave

Work Unit 3-5.

1. A conductor that transfers radio frequency (RF) energy from the transmitter to the antenna or from the antenna to the receiver
2. A motionless wave on an antenna
3. d
4. b
5. a
6. c
7. Ease of construction and readily accessible material
8. some RF loss in transmission line power, or care must be taken when using this type of line with HF or high powered equipment
9. the conductor balanced to ground

STUDY UNIT 4

SITE SELECTION AND ANTENNA GROUNDING

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY THE TECHNICAL AND TACTICAL REQUIREMENTS OF SITE SELECTION. YOU WILL ALSO IDENTIFY VARIOUS ELECTRONIC COUNTER-COUNTERMEASURES PRECAUTIONS THAT CAN BE TAKEN WHEN SELECTING AN ANTENNA SITE. LASTLY, YOU WILL IDENTIFY VARIOUS TYPES OF GROUNDING DEVICES.

Two factors play an important role in equipment siting: optimum communications and camouflage. Unfortunately, it is seldom possible to locate your equipment, in order to communicate well and yet be hidden from enemy view, fire, or direction finding.

From a communications point of view, the ideal location for a radio antenna is as far away from cover as possible such as a bare mountaintop or out in the middle of a large field. Obviously, this does not agree with the commander's requirement to be hidden from view as much as possible; therefore, planning the location of equipment must be detailed to achieve the best results. Because you can not always obtain the best locations for your antenna sites, antenna grounding is also an important factor to consider. Probably the most frequent cause of a weak signal, especially HF signals, is poor grounding. You can easily cut your communication distance in half by not grounding the antenna. Another important factor to remember about ungrounded high powered transmitters is getting shocked, badly burned, or killed.

Work Unit 4-1. REQUIREMENTS FOR SITE SELECTION

GIVEN A LIST OF SEVERAL FACTORS FOR ANTENNA SITE SELECTION AND A LIST OF THE TYPES OF CATEGORIES THESE FACTORS FALL UNDER, MATCH THE FACTOR WITH THE APPROPRIATE CATEGORY.

The choice of an antenna site will depend on the nature of the local intervening terrain and the tactical situation. Planning should always be preceded by a careful study of terrain maps and whenever possible, by reconnaissance in order to obtain detailed information concerning the availability, accessibility, and size of desirable sites.

Technical Factors. Factors to be considered will depend on the type of equipment used and the tactical situation.

a. Location. A radio station must be located in a position that will ensure communication with all other stations with which it is to operate. To obtain efficient transmission and reception, the following factors should be considered:

(1) Hills and mountains between stations normally limit the range of radio sets. In mountainous or hilly terrain, positions relatively high on the slopes (fig 4-1) should be selected. Locations at the base of a cliff or in a deep ravine or valley should be avoided. For operation at frequencies above 30 MHz, a location that will give line-of-sight communication should be selected whenever possible.

(2) Dry ground has resistance and limits the range of the radio set. If possible, the station should be located near moist ground, which has much less resistance. Water, and in particular salt water, will greatly increase the distances that can be covered.

(3) Trees with heavy foliage absorb radio waves, and leafy trees have a more adverse effect than evergreens. The antenna should be kept clear of all foliage and dense brush.

b. Man-made obstructions

(1) A position in a tunnel or beneath an underpass or steel bridge (fig 4-1) should not be selected. Transmission and reception under these conditions are almost impossible because of high absorption of RF waves.

(2) Buildings located between radio stations, particularly steel and reinforced concrete structures, hinder transmission and reception.

(3) All types of pole wire lines, such as telephone, telegraph, and high-tension power lines, should be avoided in selecting a site for a radio station. Such wire lines absorb power from radiating antennas located in their vicinity. They also introduce hum and noise interference in receiving antennas.

(4) Positions adjacent to heavily traveled roads and highways should be avoided. In addition to the noise and confusion caused by tanks and trucks, ignition systems in these vehicles may cause electrical interference.

(5) Battery-charging units and generators should not be located close to the radio station.

(6) Radio stations should not be located close to each other.

(7) Radio stations should be located in relatively quiet areas. Copying weak signals requires great concentration by the operator, and his attention should not be diverted by extraneous noises.

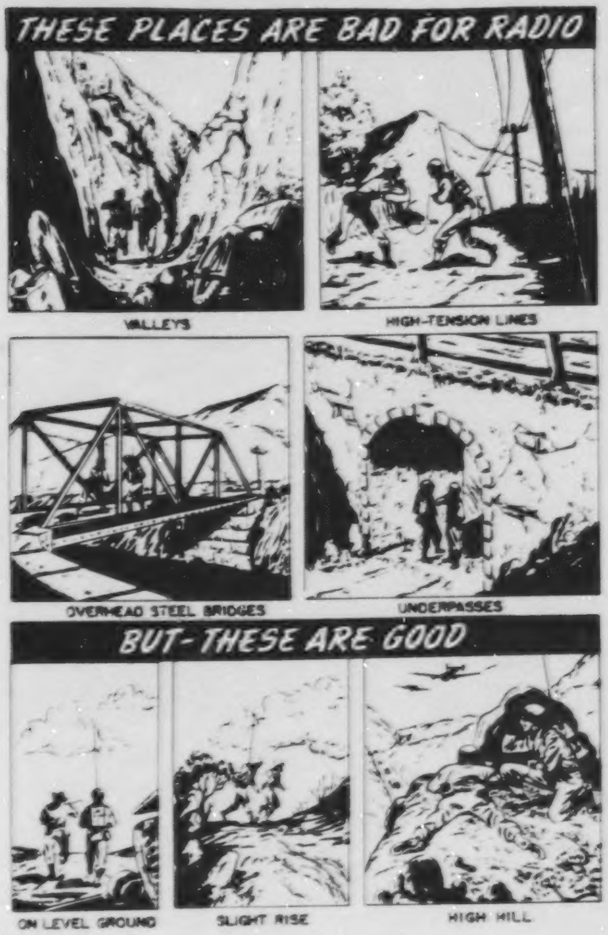

THESE PLACES ARE BAD FOR RADIO
VALLEYS
HIGH-TENSION LINES
OVERHEAD STEEL BRIDGES
UNDERPASSES
BUT-THESE ARE GOOD
ON LEVEL GROUND
SLIGHT RISE
HIGH HILL

Fig 4-1. Antenna siting.

Tactical Factors

a. Local command requirements. Radio stations should be located some distance from the unit headquarters or command post that they serve. Thus, long-range enemy artillery fire, missiles, or aerial bombardment, directed at the stations as a result of enemy direction finding, will not strike the command post area.

b. Cover and concealment. The locations selected should provide the best cover and concealment possible, consistent with good transmission and reception. Perfect cover and concealment may impair transmission and reception. The amount of permissible impairment depends on the range required, the power of the transmitter, the sensitivity of the receiver, the efficiency of the antenna system, and the nature of the terrain. When a set is being used to communicate over a distance that is well under the maximum range, some sacrifice of communication efficiency can be made to permit better concealment of the set from enemy observation.

Practical Considerations

a. Pack sets have sufficiently long cordage to permit operation from cover, while the radio set is below the surface of the surrounding terrain and the antenna is in the clear.

b. Some sets can be controlled remotely from distances of 100 feet or more. Sets of this type can be set up in a relatively exposed position, while the operator remains concealed.

c. Antennas of all radio sets must extend above the surface of the ground to permit normal communications.

d. Small tactical set antennas are usually of the whip type. These antennas are difficult to see from a distance, especially if they are not silhouetted against the sky.

e. Open crests of hills and mountains must be avoided. A slightly defiladed position just behind the crest gives better concealment and sometimes provides better transmission.

f. All permanent and semipermanent positions should be properly camouflaged for protection against both aerial and ground observation. However, the antenna should not touch trees, brush, or camouflage material.

Local communications. Contact must be maintained between the radio set and the message center at all times, either by local messenger or field telephone. The station should also be readily accessible to the unit commander and his staff.

Final considerations. It is almost impossible to select a radio site that will satisfy all technical and tactical requirements . Therefore, a compromise is usually necessary, and the best site available is selected. It is also a good idea to select both a primary and an alternate site. Then, if radio communication cannot be established at the primary location, the set can be moved a short distance to the alternate position.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

Matching: Column 1 (items 1-5) lists several factors for antenna site selection. Column 2 (a and b) lists the types of categories these factors fall under (either technical or tactical). Match the factor in column 1 with its specific category in column 2. Write your answers in the spaces provided.

Column 1

Factors

______1. Local command requirements
______2. Location
______3. Man-made obstructions
______4. Cover and concealment
______5. Practical considerations

Column 2

Type of Category

a. Technical
b. Tactical

Work Unit 4-2. ELECTRONIC WARFARE ANTENNA SITING

DEFINE ANTENNA MASKING.

NAME ONE ADVANTAGE OF USING DIRECTIONAL HORIZONTALLY POLARIZED ANTENNAS IN AN EW ENVIRONMENT.

Antenna Masking

Antenna masking (fig 4-2) is the technique of hiding radio signals behind terrain. It is an inexpensive way to confuse RDF efforts. VHF radio waves bend; they are flected by buildings and mountains, and absorbed by trees. When this happens, it is difficult to determine the original direction from which the wave was transmitted, but the ability to hear the signal is minimally affected. A radio operator can advantageously use this principle by attempting to place terrain obstacles between the transmitter and the FEBA, while affording an unblocked path to the intended receivers. Hills, lakes, and dense forest also provide terrain obstacles. Antenna masking also occurs when antennas are positioned on the back slopes of hills. A radio operator should also erect antennas as low as adequate communications permit, and, in all cases, antennas should be camouflaged to blend with terrain.

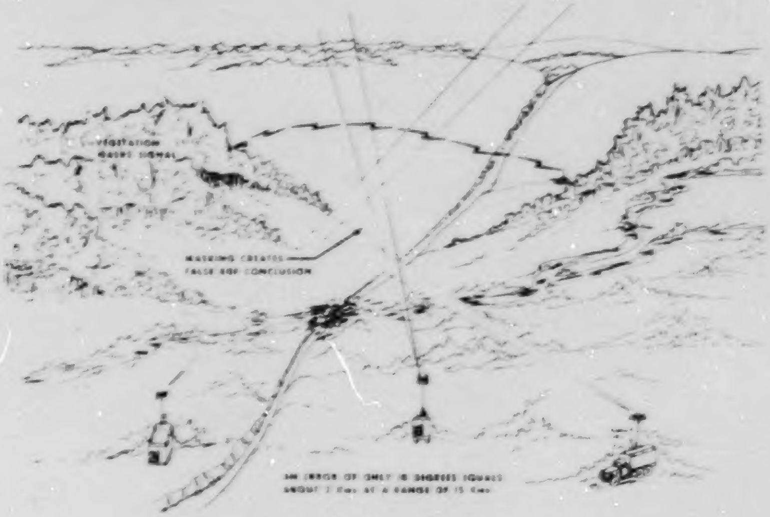

VEGETATION MASKS SIGNAL
MASKING CREATES FALSE RDF CONCLUSION
AN ERROR OF ONLY 10 DEGREES EQUALS ABOUT 2 Kms AT A RANGE OF 15 Kms

Fig 4-2. Antenna masking.

Antenna dispersion

Antennas must be dispersed so that all of the radiations are not coming from one central antenna form. Terrain analysis can show us antenna locations which provide natural masking from the enemy. We need to plan for as many alternate locations as possible. This terrain analysis can be aided with the use of the services of the Electro-magnetic Compatibility Analysis Center (ECAC) see appendix II.

Use Directional Horizontally Polarized Antennas

For versatility, the omni-directional vertically polarized antenna is best. The flexibility provided by omni-directional antennas is important to the commander during the attack, when it is difficult to maintain correct orientation for horizontally polarized directional antennas. Vertically polarized omni-directional antennas are required for communications between moving vehicles. However, when ECCM is considered, the omni-directional antenna has one chief disadvantage--danger. Omni-directional antenna signals travel in a 360-degree radius and usually well across the FEBA where they are susceptible to interception and RDF. Horizontally polarized directional antennas should be considered for lateral communications whenever possible.

Enemy forces primarily use Adcock and vertical loop RDF antennas which are designed for optimum performance when receiving vertically polarized radio waves. A horizontally polarized transmitting VHF antenna will radiate a predominantly horizontally polarized wave from ten to forty kilometers from the transmitter. The horizontally polarized wave will create some bearing error in an Adcock antenna, and a very large error in a vertical loop antenna. This may cause an error as much five times greater than the usual operational error (about 20 degrees), creating unusable RDF bearings. It is impossible for an RDF operator to continually adjust tactical ground-operated RDF equipment, particularly Adcock antennas, to compensate for both vertical and horizontal waves. If US forces would use both vertically and horizontally polarized omni-directional and directional VHF antennas along with good COMSEC practices, direction finding would become more difficult and expensive for our adversaries.

End- or center-fed half-wave or quarter-wave directional antennas offer many advantages with VHF radios. For example, a doublet antenna provides a more directional signal antenna which can reduce the enemy's ability to intercept the signal by 20 to 40 percent. It also provides a 20 percent greater range, especially in wooded areas, by increasing ERP in the desired direction. This is a useful ECCM technique.

The five advantages of using directional horizontal polarization antennas in an EW environment are:

(a) The horizontal antenna produces a more stable signal in the presence of interference (jamming).

(b) The horizontal antenna produces a more stable signal when used in or near dense woods.

(c) The horizontal antenna is more readily camouflaged without loss of signal. Small changes in antenna location do not cause large variations in signal strength.

(d) Small changes in antenna location do not cause large variations in signal strength.

(e) The horizontal antenna is more difficult to direction find because of polarization and because its signal can be directed to intended recipients and away from enemy RDF in many applications.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Define antenna masking.

2. Name one advantage of using horizontal polarization in an EW environment.

Work Unit 4-3. GROUNDS AND COUNTERPOISES

DEFINE GROUNDING RODS.

DEFINE RADIAL GROUNDS.

DEFINE COUNTERPOISE.

DESCRIBE A GROUND SCREEN.

Types of Grounds

When grounded antennas are used, it is especially important that the ground have as high a conductivity as possible. This is necessary to reduce ground losses and to provide the best possible reflecting surface for the down-going radiated energy from the antenna. Since at low and medium frequencies the ground acts as a sufficiently good conductor, the problem is how to make connection to the ground in such a way as to introduce the least possible amount of resistance in the ground connection. At higher frequencies, artificial grounds constructed of large metal surfaces are common.

The ground connection takes many forms, depending on the type of installation and the loss that can be tolerated. For fixed station installations, very elaborate ground systems are used. These are frequently arranged over very large areas so that they operate as part of the reflecting surface in addition to making the connection to ground itself. In many simple field installations, the ground connection is made by means of one or more metal rods driven into the earth. Where more satisfactory arrangements cannot be made, it may be possible to make ground connections to existing devices which are themselves grounded. Metal structures or underground pipe systems (such as water pipes) commonly are used as ground connections. In an emergency, a ground connection can be made by plunging one or more bayonets into the earth.

Sometimes, when an antenna must be erected over soil having a very low conductivity, it is advisable to treat the soil directly to reduce its resistance. Occasionally, the soil is mixed with a quantity of coal dust for this purpose or it can be treated with substances which are highly conductive when in solution. Some of these substances, listed in order of preference, are sodium chloride (common salt), calcium chloride, copper sulphate (blue vitriol), magnesium sulphate (Epsom salt), and the potassium nitrate (saltpeter). The amount required depends on the type of soil and its moisture content. When these substances are used, it is important that they do not get into nearby drinking water supplies.

Ground Rods

With a less elaborate ground system, a number of ground rods can be used. These rods usually are made of galvanized iron, steel, or copperplated steel in lengths up to 8 feet. One end of the rod is pointed so that it can be driven easily into the earth. The other end frequently is fitted with some type of clamp so that the ground lead can be attached. Some ground rods are supplied with a length of ground lead already attached.

A fairly good ground connection can be made by using several ground rods, 6 to 10 feet apart, connected in parallel. If possible, the rods should be located in a moist section of ground or in a depression which will collect moisture. Ground resistance can be reduced considerably by treating the soil with any of the substances previously mentioned. A trench about a foot deep is dug around each ground rod and filled with some common rock salt, epsom salt, or any of the other materials mentioned. The trench is then flooded with water, after which it is covered with earth. To remain effective, this treatment should be renewed every few years.

For simple installations, a single ground rod can be fabricated in the field from pipe or conduit. It is important that a low resistance connection be made between the ground wire and the ground rod. The rod should be cleaned thoroughly by scraping and sandpapering at the point where the connection is to be made, and a clean ground clamp installed. A ground wire can then be soldered or joined to the clamp. The joint should be covered with tape to prevent an increase in resistance caused by oxidation.

Other field expedient ground rods are metal fence posts, steel reinforcing rods, water pipes and metal building frame.

Radial Grounds

Radial grounds (fig 4-3) consist of a number of bare conductors arranged radially and connected. The conductors, which may be from a tenth to a half-wave length or more, are buried a short distance beneath the surface of the earth. If possible, bare metal plates should be attached to the wire ends which improves the quality of the ground.

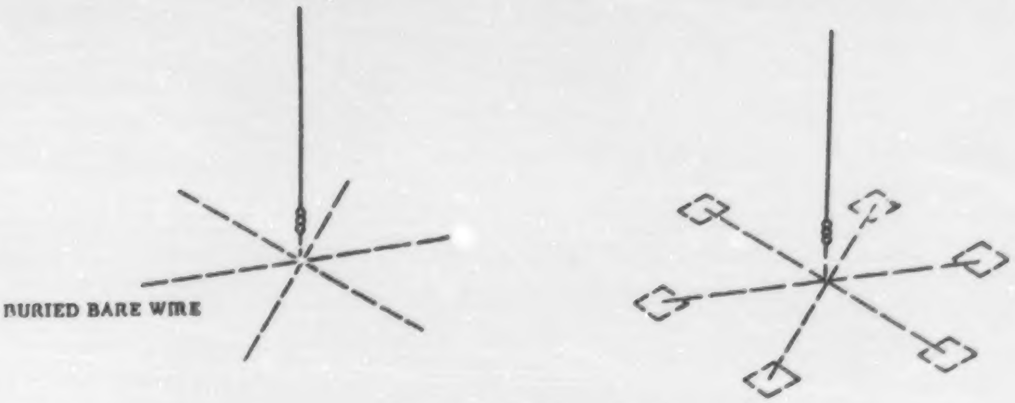


Fig 4-3. Radial grounding.

Counterpoise

When an actual ground connection cannot be used because of the high resistance of the soil or because a large buried ground system is not practicable, counterpoise may replace the usual direct ground connection in which current actually flows to and from the antenna through the ground itself. The counterpoise (fig 4-4) consists of a structure made of wire, which is erected a short distance off the ground and insulated from the ground. The size of the counterpoise should be at least equal to or preferably larger than the size of the antenna.

When the antenna is mounted vertically, the counterpoise should be made into a simple geometric pattern such as those shown in figure 4-4. Perfect symmetry is not required, but the counterpoise should extend for equal distances in all directions from the antenna.

If some VHF antenna installations are on vehicles, the metal roof of the vehicle is used as a counterpoise for the antenna.

Small counterpoises of metal mesh are sometimes used with special VHF antennas that must be located a considerable distance above the ground. This counterpoise provides an artificial ground that helps to produce the required radiation pattern.

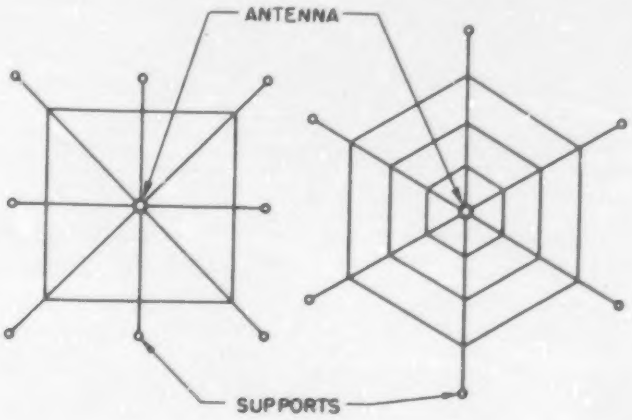


Fig 4-4. Counterpoise.

Ground Screen

A ground screen consists of a fairly large area of metal mesh or screen that is laid on the surface of the ground under the antenna. Its purpose is to simulate to some extent the effect of a perfect conducting ground under the antenna.

There are two specific advantages that can be gained through use of a ground screen. First, the ground screen reduces ground absorption losses that occur when an antenna is erected over imperfectly conducting ground and second, the height of the antenna can be set accurately. As a result of this, the radiation resistance of the antenna can be determined, and the radiation patterns of the antenna can be predicted more accurately.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What are grounding rods?
2. What are radial grounds?
3. What is counterpoise?
4. Describe a ground screen.

SUMMARY REVIEW

In this study unit, you have learned about the technical and tactical requirements of antenna site selection. You have learned various ECCM precautions that can be taken when selecting an antenna site. You have also learned about the various types of antenna grounds, which will help to improve communications.

Answers to Study Unit #4 Exercises

Work Unit 4-1.

1. b
2. a
3. a
4. b
5. b

Work Unit 4-2.

1. The technique of hiding radio signals behind terrain

2. (Any one of the following five is correct)

   (1) The horizontal antenna produces a more stable signal in the presence of interference (jamming).
   (2) The horizontal antenna produces a more stable signal when used in or near dense woods.
   (3) The horizontal antenna is more readily camouflaged without loss of signal.
   (4) Small changes in antenna location do not cause large variations in signal strength.
   (5) The horizontal antenna is more difficult to direction find because of polarization and because its signal can be directed to intended recipients and away from enemy RDF in many applications.

Work Unit 4-3.

1. Galvanized iron, steel, or copper plated steel in lengths up to 8 feet with one end of the rod pointed and the other end clamped.

2. A number of bare conductors arranged readily connected and buried a short distance beneath the surface of the earth.

3. A structure made of wire, which is executed a short distance off the ground and insulated from the ground.

4. A ground screen consists of a fairly large area of metal mesh or screen that is laid on the surface of the ground under the antenna.

ANTENNA CONSTRUCTION AND PROPOGATION OF RADIO WAVES

Review Lesson

Instructions: This review lesson is designed to aid you in preparing for your final examination. You should try to complete this lesson without the aid of reference materials, but if you do not know an answer, look it up and remember what it is. The enclosed answer sheet must be filled out according to the instructions on its reverse side and mailed to MCI using the envelope provided. The questions you miss will be listed with references on a feedback sheet (MCI-R69), which will be mailed to your commanding officer with your final exam. You should study the reference materials for the questions you missed before taking the final exam.

A. Multiple choice: Select the ONE answer that BEST completes the statement or answers the question. After the corresponding number on the answer sheet, blacken the appropriate circle.

Value: 1 point each

1. What part of a radio set is used for sending radio signals?

   a. Demodulator
   b. Transmitter
   c. Receiver
   d. Amplifier

2. What component of a radio set takes the electromagnetic waves and developes an electrical signal, which amplifies and demodulates into an audible signal?

   a. Antenna
   b. Receiver
   c. Transmitter
   d. Power converter

3. What device is used for radiating or receiving radio waves?

   a. Receiver
   b. Transmitter
   c. Antenna
   d. Demodulator

4. What provides operating voltage to a radio set?

   a. Power supply
   b. Direct current
   c. Alternating current
   d. Carrier wave

5. Electromagnetic energy radiated from an antenna is known as _______ waves.

   a. sky
   b. ground
   c. magnetic
   d. radio

6. The number of complete cycles that occurs in one second determines the

   a. speed at which electromagnetic energy travels through space.
   b. frequency of a radio wave.
   c. amount of energy available in a power supply.
   d. type of power supply needed to operate a radio set.

7. What is the formula for finding the wavelength of an antenna when the frequency is known?

   a. $\frac{3000}{f}$
   b. $\frac{300000}{f}$
   c. $\frac{3000000}{f}$
   d. $\frac{300000000}{f}$

8. What type of wave acts as a medium for the transmission of information signals?

   a. Carrier
   b. Frequency
   c. Transmission
   d. Received

9. The process which varies or modifies either the frequency or amplitude of the carrier waveform is known as the

   a. critical frequency.
   b. transmission.
   c. modulation.
   d. carrier wave converter.

10. What type of modulation varies the power output of a transmitter?

    a. FM
    b. FSK
    c. SSB
    d. AM

11. What is the process called which varies the frequency of an unmodulated carrier wave in proportion to the amplitude of the modulating signal?

    a. FM
    b. FSK
    c. AM
    d. SSB

12. A gaseous mass which envelops the earth describes the

    a. autmosphere.
    b. source of ionization.
    c. atmosphere.
    d. regious in outer space.

13. The atmosphere is composed of three regions. Name them in order of their relative heights.

    a. Troposphere, ionosphere, and stratosphere
    b. Stratospnere, troposphere, and ionosphere
    c. Troposhere, stratosphere and ionosphere
    d. Ionosphere, troposphere, and stratosphere

14. A ground wave is a radio wave that travels

    a. skyward.
    b. skyward and near the earth's surface.
    c. near the skip zone.
    d. near the earth's surface.

15. The direct ground reflected and surface waves are all components of the __________ wave.

    a. sky
    b. single hop
    c. tropospheric
    d. ground

16. What type of radio wave depends on the ionosphere to provide signal paths between transmitter and receiver?

    a. Sky
    b. Ground
    c. Direct
    d. Ground reflected

17. An area bounded by the outer edge of the usable ground wave propagation and the point nearest the antenna at which the sky wave returns to earth is known as the

    a. skip area.
    b. skip zone.
    c. unusable zone.
    d. skip distance.

18. Which region of the ionosphere has little effect in bending the paths of high frequency radio waves?

    a. F1
    b. F2
    c. E
    d. D

19. During the day, all regions within the ionosphere are ionized. At night only the ________ regions remain ionized.

    a. D
    b. E
    c. F
    d. G

20. The chief factor that controls long distance communication is the _______ ________ of the ionized layer.

    a. expect -- location
    b. ionization -- density
    c. upper -- region
    d. trapped -- waves

21. Which two layers of the ionosphere are the most highly ionized?

    a. D and E
    b. D and F
    c. E and F
    d. D and F-2

22. The highest frequency at which waves sent vertically upward are reflected directly back to earth defines

    a. the highest frequency of transmission.
    b. modes of transmission.
    c. critical frequency.
    d. interference frequency.

23. The frequencies that return to earth from a fixed angle of departure are known as the MUF. The MUF used in predicting the operating frequencies refers to the

    a. maximum transmission distance possible for a given operating frequency.
    b. minimum transmission distance possible for a given operating frequency.
    c. lowest frequency that will provide communication over a specified distance at a given time.
    d. highest frequency that will provide communication over a specified distance at a given time.

24. Waves of frequency that are transmitted above the __________ will pass through the ionosphere and escape into space.

    a. MUF
    b. FOT
    c. LUF
    d. UMF

25. The lowest limiting frequency for satisfactory sky-wave communication for a radio circuit at a particular time is known as the

a. LUF.
b. LOF.
c. LTF.
d. LHF.

26. The periodic increase and decrease of received radio strength is called

a. noise.
b. reflection.
c. fading.
d. interference.

27. Ground-wave propagation is extremely useful for communication at

a. any frequency.
b. low frequencies.
c. high frequencies.
d. superhigh frequencies.

28. What types of radio wave propagation are useful at the medium frequency band?

a. Sky only
b. Sky and reflected
c. Ground only
d. Sky and ground

29. In the high frequency band what are the two types of wave propagation called?

a. Direct and sky
b. Reflected and direct
c. Reflected and ground
d. Sky and ground

30. Which of the ground wave components listed below provides the best communications path when operating in the very-high-frequency band?

a. Ground reflected wave
b. Surface wave
c. Direct wave
d. Critical wave

31. The direct wave component of the ground wave is the only reliable propagation path available when transmitting in the _________ frequency band.

a. HF
b. ELF
c. ULF
d. UHF

32. A device which converts the output power delivered by a radio transmitter into an electromagnetic field, that is radiated through space is the function of a

a. transmitting antenna.
b. power converter.
c. RF amplifier.
d. AF amplifier.

33. What is the purpose of a receiving antenna?

a. To send received signals to the modulator
b. To vary the frequency of a radio wave
c. To operate as a signal source for the receiver
d. To radiate energy into space

34. If a transmitter is supplying power to an antenna, the fluctuating energy sets up two fields. Which of these two fields remain at a short distance from the antenna and beyond?

a. Radiation
b. Inductive
c. Magnetic
d. Electric

35. The radiation field is composed of two components. They are the electric __________ components.

a. induction
b. magnetic
c. electron
d. oscillation

36. What field is formed from the electric and magnetic components of a radiated wave?

a. Electroinductive
b. Electromagnetic
c. Magneticinduction
d. Electromotive

37. Polarization of a radiated wave is determined by the direction of the lines of force making up the ___________ field.

a. magnetic
b. induction
c. electric
d. radiation

38. There are two types of antenna polarization. What are these types of polarization?

a. Vertical and omni-directional
b. Vertical and horizontal
c. Horizontal and directional
d. Azimuthal and vertical

39. At low and medium frequencies, ground-wave transmission is used extensively. What type of polarization must be used?

a. Vertical
b. Horizontal
c. Directional
d. Azimuthal

40. Why is it better to horizontally polarize antennas at high frequencies?

a. They can be made to radiate effectively at high angles.
b. They are omni-directional.
c. Because vertically radiated waves can not be refracted from the ionosphere.
d. Because vertically polarized antennas have inherent directional properties.

41. At the very-high and ultra-high frequency bands, which type(s) of antenna polarization should be used?

a. Vertical polarization only
b. Horizontal polarization only
c. Neither vertical nor horizontal
d. Either vertical or horizontal polarization

42. The RC-292 is a(n) ____________________________________ antenna.

a. center fed whip
b. long wire
c. fixed, mast mounted, log periodic
d. elevated, wide band, modified ground plane

43. Which antenna array assembly consist of a folding boom supporting a planar array of seven log periodic dipole elements?

a. AS-1729
b. AS-2236
c. AS-2851/TR
d. AS-2259/GR

44. Which antenna system consist of a collapsible folding log periodic shaped in the form of a square?

a. AS-2236
b. AS-2950
c. RC-290
d. RC-292

45. A dipole antenna which consists of eight lightweight coaxial mast sections and four radiating elements that also serve as guys is a(n) __________ antenna.

a. AS-892
b. AS-2851
c. AS-2236
d. AS-2259

46. By aligning the antenna with an azimuth to the outstation and adding or subtracting the wave angle, the major lobe of the ______________________ antenna can be directed toward the intended receiver.

a. half-wave dipole
b. long wire
c. quarter-wave whip
d. ground plane

47. What happens to a half-rhombic antenna, when terminated in a resistor?

a. It becomes uni-directional
b. It becomes omnm-directional
c. It becomes bi-directional
d. It becomes directional

48. When making a field expedient ground plane antenna, at what length should the vertical and ground plane elements be cut?

a. 1/4-wave
b. 1/2-wave
c. 3/4-wave
d. 1-wave

49. A conductor that transfers radio frequency energy from the transmitter to the antenna is called a ___________________________ line.

a. repeater
b. carrier
c. transmission
d. pulse

50. A standing wave is described as a

a. motionless wave on an antenna that is caused by a perfect match.
b. motionless wave on an antenna that is caused by a mismatch.
c. moving wave on an antenna that is caused by a perfect match.
d. motionless wave on an antenna that causes a perfect match.

51. What are the advantages to using the twisted pair transmission line?

a. There is an RF energy loss in the line and readily accessible material
b. This type of line permits ease of construction and readily accessible material
c. It can be used with HF equipment without hazard and ease of construction
d. This type of line is balanced to ground and used with Hf equipment without hazard

52. One disadvantage of using the twisted pair transmission line is that

a. it's too difficult to work with.
b. it's balanced to ground.
c. it's too expensive to use.
d. care must be taken to ensure that the line is capable of handling the transmitter power.

53. What is one advantage of using the shielded pair transmission line?

a. Ease of construction
b. Readily accessible material
c. Low cost of material
d. The conductors balanced to ground

54. The technique of hiding radio signals behind terrain defines

a. decoy antennas.
b. antenna dispersion.
c. remote operation.
d. antenna masking.

55. What is one advantage of using directional horizontally polarized antennas in an EW environment?

a. The antenna is immune to jamming
b. The antenna can be used on vehicles while on the move
c. The antenna will transmit in a 360° radius
d. A directional, horizontally polarized antenna is difficult for direction finding equipment to find

56. Grounding devices made of galvanized iron or steel in lengths up to eight feet are called

a. counterpoise.
b. radial grounds.
c. grounding rods.
d. grounding screens.

57. What are radial grounds?

a. A structure made of wire which is erected a short distance above the ground.
b. A large area of metal mesh or screen laid on the ground under an antenna.
c. A large number of galvanized iron rods connected in parallel.
d. A number of bare conductors arranged radially/and connected.

58. What is a counterpoise?

a. A structure made of wire which is erected a short distance off the ground and insulated from the ground.
b. A large area of metal mesh or screen that is laid on the surface of the ground under an antenna.
c. A number of bare conductors arranged radially and connected.
d. A large number of galvanized metal rods connected in a series.

59. What type of ground system consists of a fairly large area of metal mesh or screen that is laid on the surface under an antenna?

a. Radial grounds
b. Ground screen
c. Grounding rods
d. Counterpoise

B. Matching: Read the following directions carefully for each of the groups of items below. For each item select the one letter (a., b., c., or d.) indicating your choice. After the corresponding number on the answer sheet, blacken the appropriate circle.

Value: 1 point each

GROUP I

In the group of items below (60-62) match the atmospheric layers in column 1, with the description in column 2.

Column 1 Atmospheric layer	Column 2 Description
60. Troposphere	a. The region of the atmosphere which extends from the surface of the earth to a height of about 6.8 miles
61. Ionosphere	b. The region of the earth's atmosphere composed of several distinct layers
62. Stratosphere	c. The region of earth's atmosphere where the temperature remains nearly constant

GROUP 2

In the group of items below (63-68), match the advantages of vertical and horizontal polarization in column 1, with the types of antenna polarization in column 2.

Column 1

Advantages of vertical and horizontal polarization

63. Less affected by reflections from aircraft flying over the transmission path
64. Picks up less interference from VHF and UHF broadcast transmission
65. Useful if it is desired to minimizing interference from certain directions
66. Useful when communicating with moving vehicles
67. Suffers lower losses when located near dense forests
68. Less apt to pick up manmade interference

Column 2

Types of antenna polarization

a. Vertical
b. Horizontal

GROUP 3

In the groups of items below (69-71) and (72-75) match the field expedient antennas in column 1, with the illustration in column 2.

Column 1

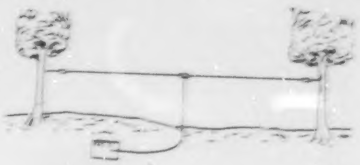
Field expedient antenna

69. Half-Rhombic
70. Long wire
71. Half wave dipole

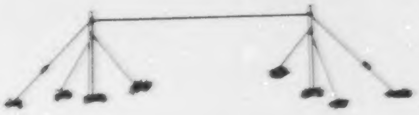
Column 2

Illustration

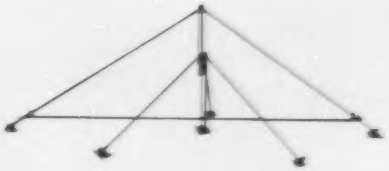
a.



b.



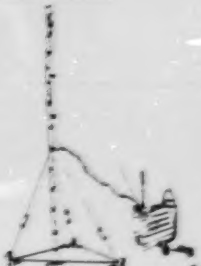
c.



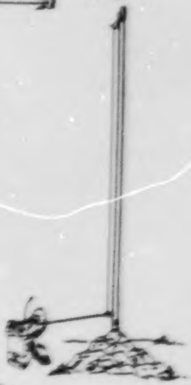
GROUP 4

Column 1 Field expedient antenna	Column 2 Illustration
72. 1/4 wave whip	a.
73. sloping V	b.
74. Field expedient ground plane	c.
75. Two element yagi	d.

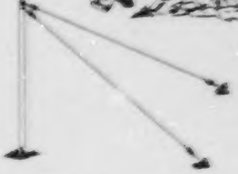
a.



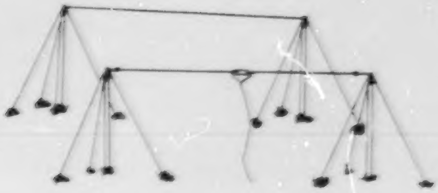
b.



c.



d.



GROUP 5

In the group of items below (76-80) match the factors for antenna sight selection in column 1, with the types of catagories in column 20.

Column 1 Factors	Column 2 Types of category
76. Man-made obstructions	a. Tactical
77. Local command requirements	b. Technical
78. Practical considerations	
79. Location	
80. Cover and concealment	

GROUP 6

In the group of items below (81-84) match the types of transmission in column 1, with the illustration in column 2.

Column 1

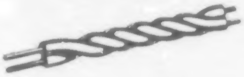
Types of transmissions

81. Shielded pair
82. Twisted pair
83. Coaxial
84. Parallel two-wire

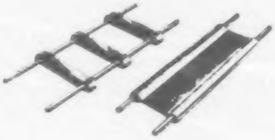
Column 2

Illustrations

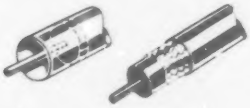
a.



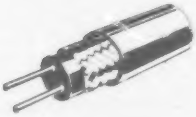
b.



c.



d.



Total Points: 84

* * *

APPENDIX I

FIELD EXPEDIENT CONSTRUCTION

This appendix discusses some field expedient solutions to repairing tactical whip and ground plane antennas, if they become broken or damaged. This appendix also covers seven field expedient antennas which can be used along with conventional tactical antennas or in place of these tactical antennas.

When you fabricate an antenna, there is one important fact that you must keep in mind; the location of the station(s) you will need to communicate with. The direction and distance are critical factors and the selection of the right type of antenna is important. Basically, there are three types of antennas according to the directional characteristics, as shown in figure AI-1.

OMNI-Directional	**All directions**
BI-Directional	**Any two opposite directions**
UNI-Directional	**Any one direction**

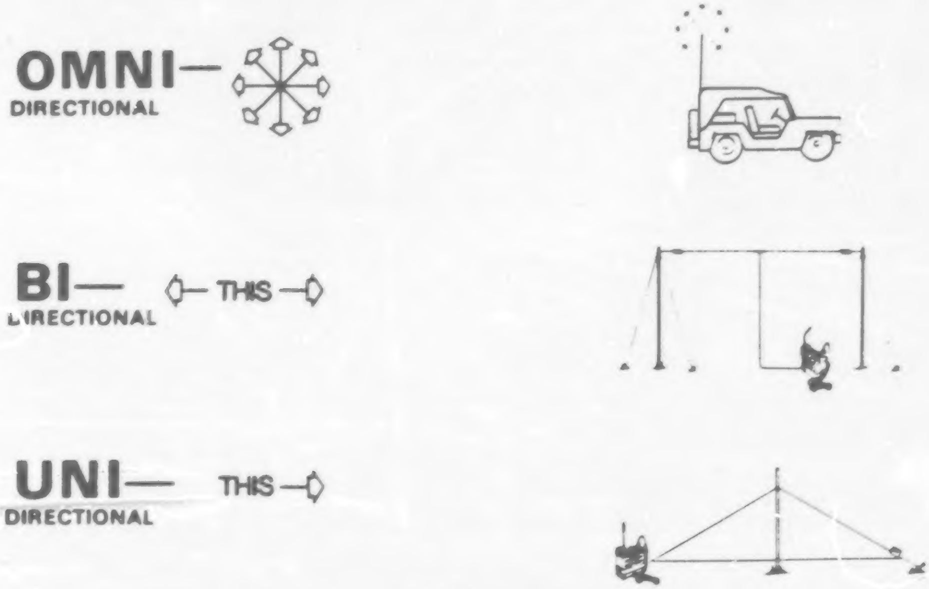


Fig AI-1. Directional characteristics.

__Note:__ Appendix I is professional reference material designed to enhance your abilities ONLY; this information is not tested in this course.

Omni-Directional Antennas

The vertical whip antenna is the most widely used omni-directional antenna ound in the military. The tactical communicator is most familiar with the whip antenna used on vehicles, and the ground plane antenna which is usually mounted on masts or other structures.

The vertical whip is omni-(all) directional, and its efficiency is related to the transmitting frequency and antenna height. At lower frequencies its efficiency is very low, but as the frequency is increased, its efficiency also increases. The problem with height can be helped by placing the antenna on top of a hill or by fastening it to a pole or tree to increase its height above surrounding structures.

If your whip antenna is damaged or missing, consider the following quick solutions to your problem:

a. Metallic Whips. If a metailic whip antenna becomes broken into two pieces a splint is the quickest repair you can make figure AI-2. The following steps are performed when repairing this type of brake:

(1) Scrape off the paint three to six inches from the broken ends.

(2) Obtain about one foot of copper wire or stripped WD-1.

(3) Overlay the cleared ends and wrap them together tightly with the wire. If possible, solder the connection.

(4) Place a dry stick, pole, or branch on each side of the break and wrap the splint tightly with WD-1, tape, rope or whatever is available.

If everything else is working right, you're ready to communicate.

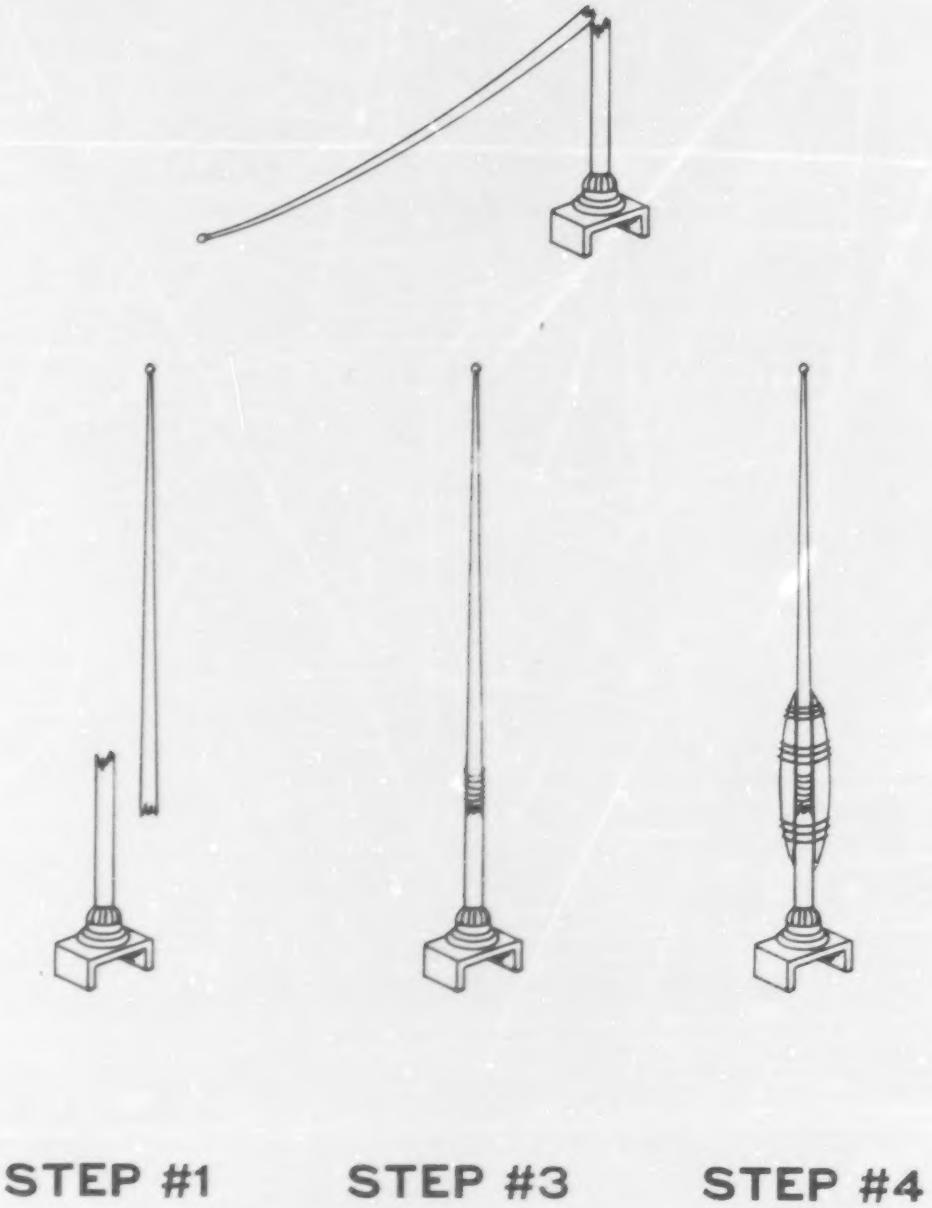

STEP #1
STEP #3
STEP #4

Fig AI-2. Metallic whip antenna (spliced).

If your metallic whip antenna is broken and the top piece is lost, perform the following steps for a quick fix (fig AI-3):

Step 1. Obtain a pole 10 feet long, about 9 feet of WD-1, and some tape.

Step 2. Scrape off the paint from the top 2 inches of the whip's stub.

Step 3. Wrap 12 inches of bare wire around the scraped portion of the stub. Wrap very tightly, pass it over the top of the stub, and jam it into the hole with a wooden peg and tape if possible.

Step 4. Tie the 10-foot pole tightly to the antenna base and stub.

Step 5. Attach the WD-1 along the length of the pole with tape. Total length of the upright WD-1 and antenna stub should not be more than 9 feet.

Step 6. Trim away any extra wire.

You are now ready to communicate. Move slowly because this mast will not withstand abuse like the original, but will serve you well in an emergency.

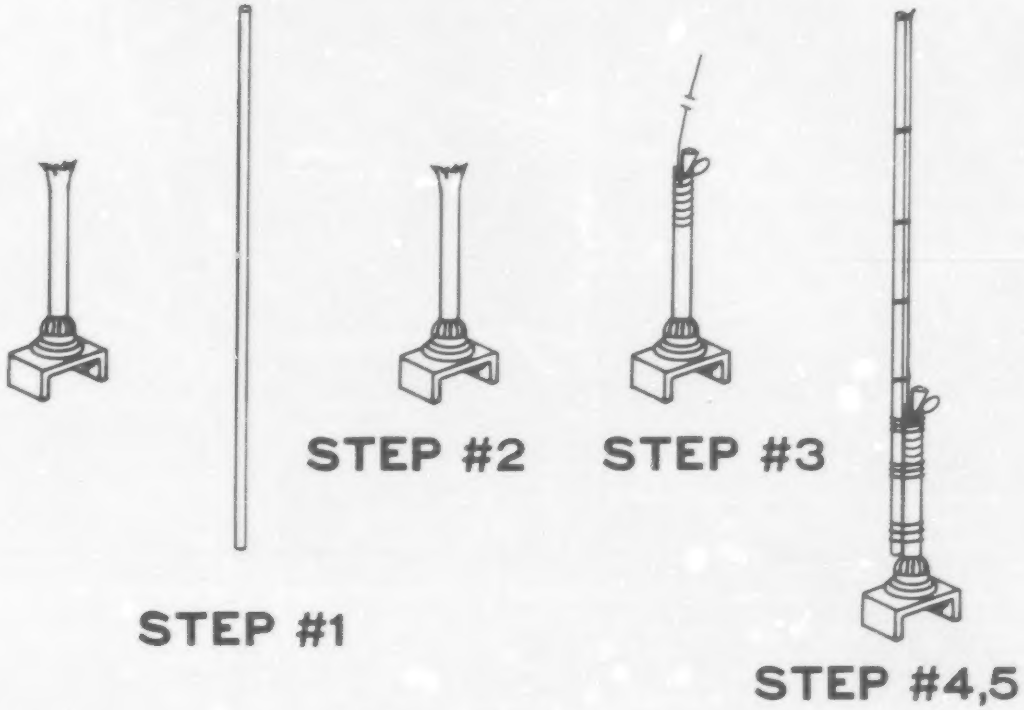


Fig AI-3. Metallic whip repair.

b. Fiberglass whips. If a fiberglass whip antenna breaks into two pieces, you cannot use a splint to fix it like we did on metal whips. To repair a broken fiberglass whip follow these simple steps (fig AI-4):

(1) Obtain a 15-foot length of coaxial cable. Measure off 5 feet and strip the rubber sleeve (cover) from the 5-foot section. Separate the braided shield from the center conductor by:

(a) Using a sharp knife, carefully cut through the outer insulation; do not cut into the braided shield. Once the insulation is cut evenly all around, pull it off leaving the braided shield exposed.

(b) Bend the coax in a loop and hold it in one hand. Using a nail or pencil, carefully separate the braided shield from the insulated center conductor. Gradually work the pencil in between the coax and the center conductor.

(c) Keeping the loop formed, stick a finger in the hole you made with the pencil and slowly pull the center conductor out of the braided shield.

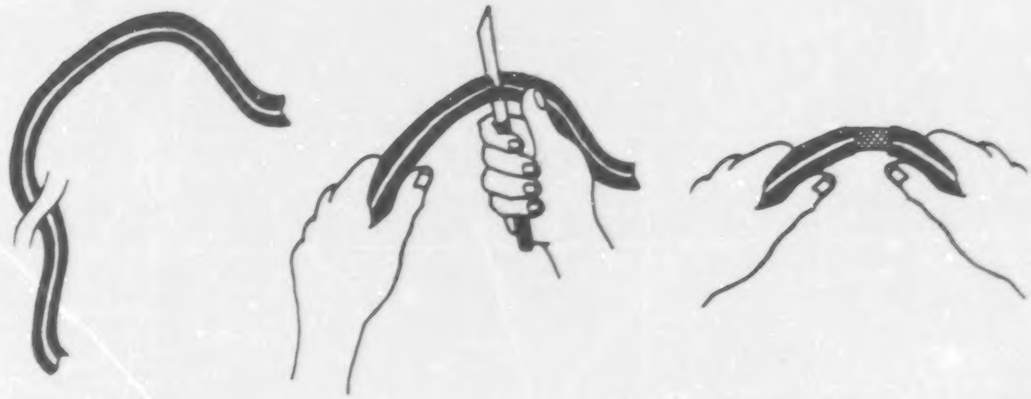
(2) Obtain a 10-foot dry pole and lash it to the antenna base.

(3) Tape the center conductor to the top of the pole.

(4) Tape the braided shield to the bottom of the pole.

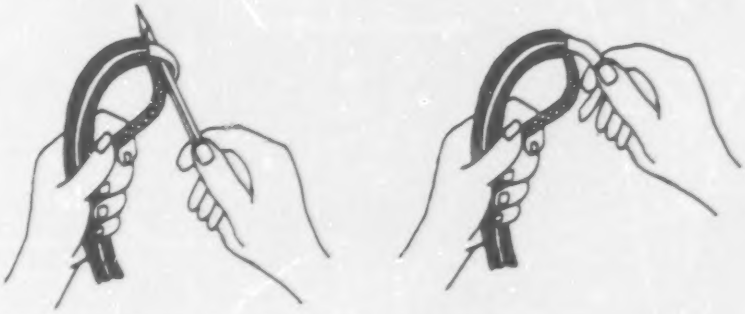
(5) Tape the stripped coax at several more places.

(6) If there's a BNC (twist lock type) connector on the coax, attach it to the radio. If not, wedge the center conductor firmly into the antenna connector and attach the braided shield to a screwhead on the radio case. Remember, this is only a temporary solution, so replace it the first chance you get.



STEP 1

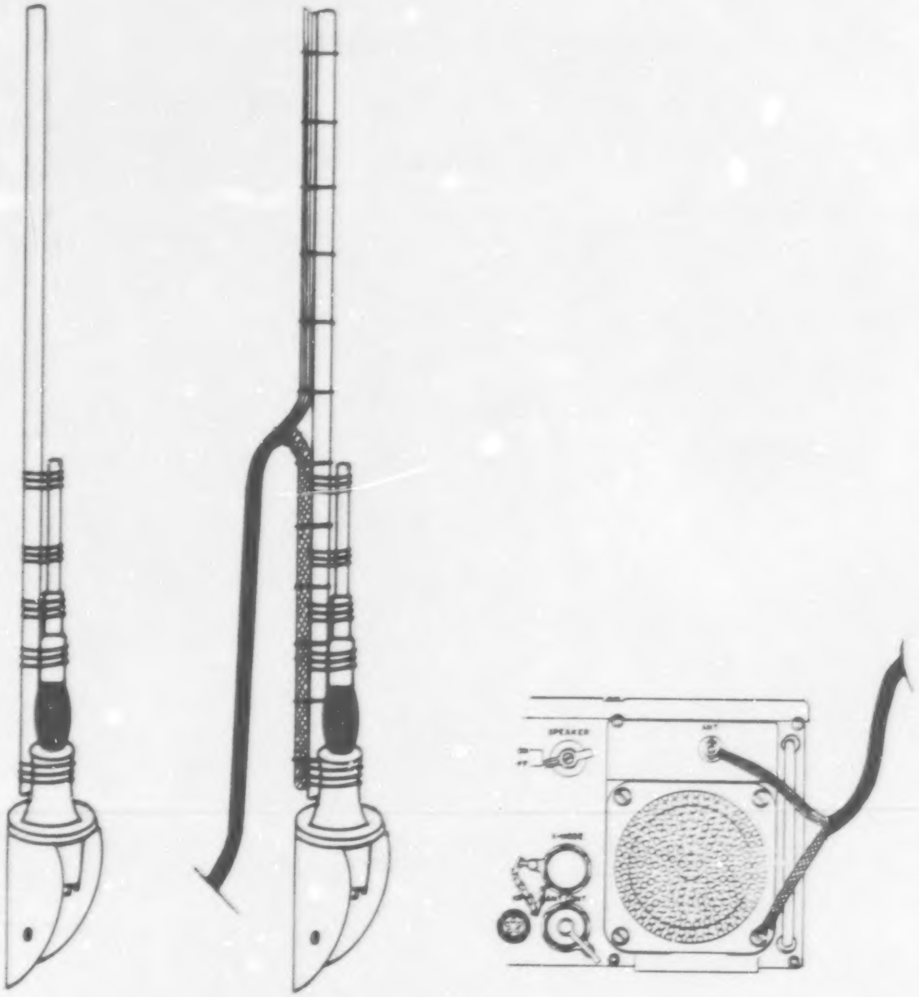
STEP 1a



STEP 1b

STEP 1c

Fig AI-4. Fiberglass whip antenna repair.



STEP 2 **STEP 3,4,5** **STEP 6**

Fig AI-4. Fibergalss whip antenna repair--continued.

c. 1/4-wave vertical antennas. To replace regular 1/4-wave whip antennas execute the following steps (fig. AI-5):

(1) Using the quick reference chart at the end of this appendix or the formula for a quarter wave, cut a piece of wire to the required length.

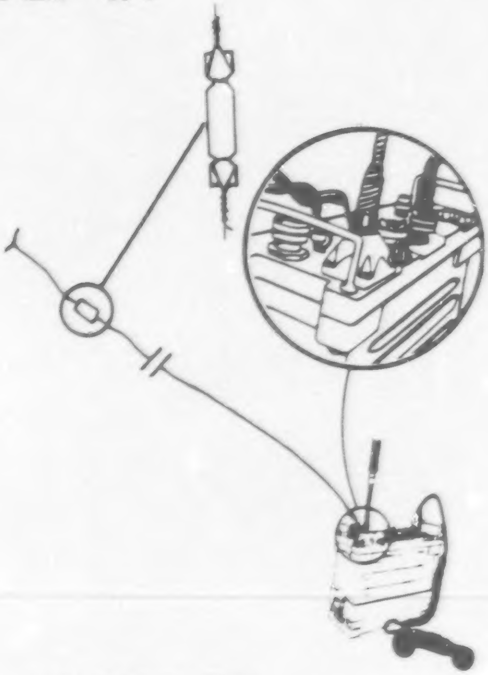
(2) Attach an insulator to one end of the wire and attach the other end to the antenna connector on the radio.

(3) Tie another piece of wire or a piece of rope to the insulator end and throw the wire/rope over a limb.

(4) Pull the antenna up until it is vertical and ready to go.

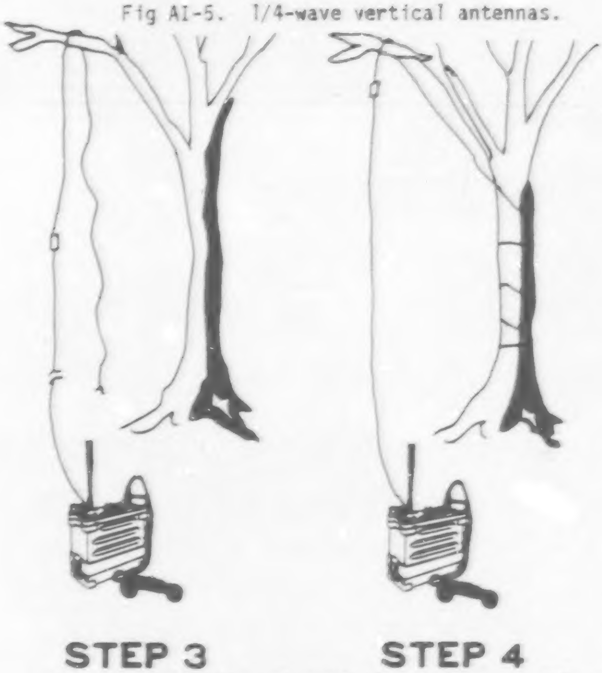
234 ÷ frequency = Antenna length in feet and inches

STEP #1



STEP #2

Fig AI-5. 1/4-wave vertical antennas.



STEP 3 **STEP 4**

Fig AI-5. 1/4-wave vertical antennas--continued.

The verticals (fig AI-6) are constructed the same way, but each has a different means of support. They are all simple and quick to erect.

If you are using insulated wire, be sure to loop the wire around the handle of the radio before attaching it to the antenna connector. If your antenna is made of bare wire, use a stake and insulator to keep the antenna wire from pulling out the antenna connector on the radio.

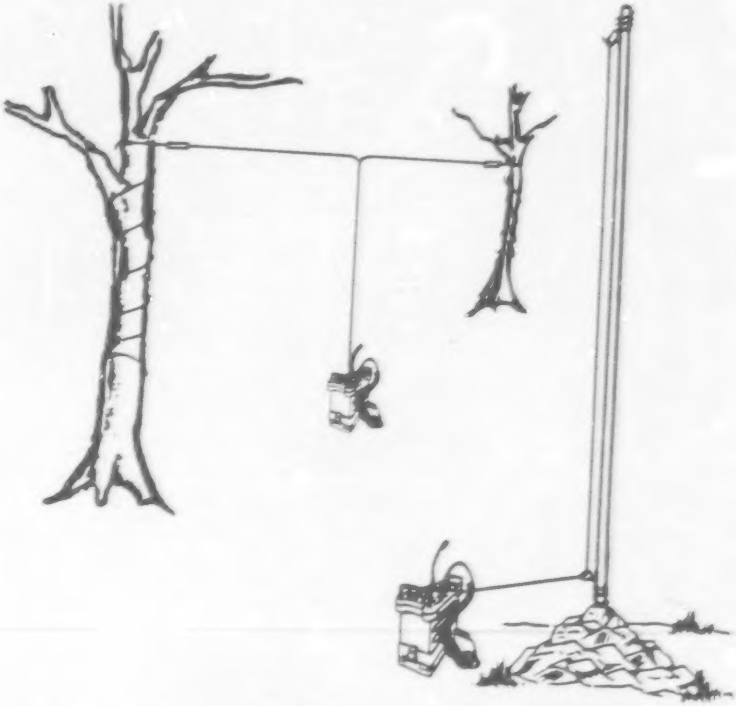


Fig AI-6. 1/4-wave vertical antennas with a different means of support.

The illustrations shown in figure AI- 7 illustrates how to rig an antenna lead-in using WD-1, which is a pair of twisted wires. Since a good electrical connection is a must, remove an inch or two of insulation from the ends of the wires. Separate the three steel strands from the four copper strands in each wire and cut the steel strands off at the insulation. Twist the four copper strands of each wire together. Connect the ends of the wires to the antenna and to the radio, and you have a usable antenna lead-in. For some antennas such as the ground plane, the wire connected to the vertical element (inner part of a receptacle on the antenna) must connect to the inner part of the antenna receptacle or to an antenna terminal on the radio set. The other wire must connect to the outer shell of the antenna receptacles. Usually you can loosen one of the screws on the receptacle shells and connect the wire at those points.

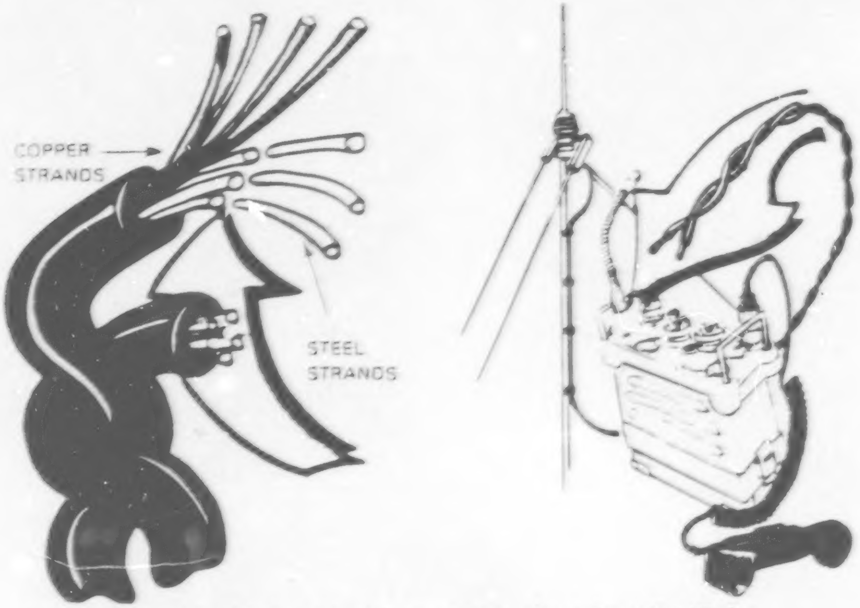


Fig AI-7. Rigging an antenna lead-in using WD-1.

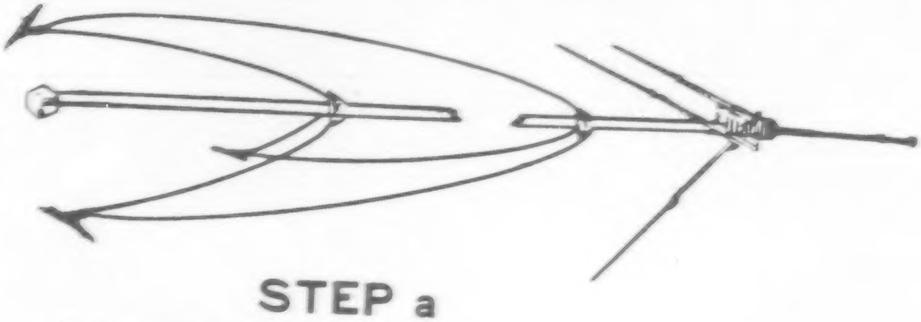
d. RC-292 ground plane antenna. The RC-292 is a highly effective, omni-directional antenna. It is usually much more effective than a whip antenna. When this antenna is damaged or not available, there are several versions that can be fabricated. To repair and/or fabricate the RC-292 antennas, here are some of the methods used:

(1) Mast and guy repair for RC-292. To repair an antenna with a broken mast section and guyline, follow these steps:

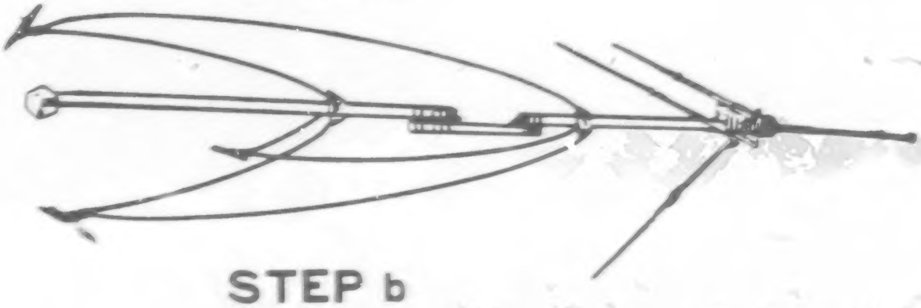
(a) Lay the broken mast end to end.

(b) Using a sturdy pole, splint the pieces of the mast together.

(c) Repair or replace the guy line, with rope or wire. If wire is used be sure to use an insulator, this will prevent the wire from radiating.



STEP a



STEP b

Fig AI-8. Mast section and guyline repair RC-292.

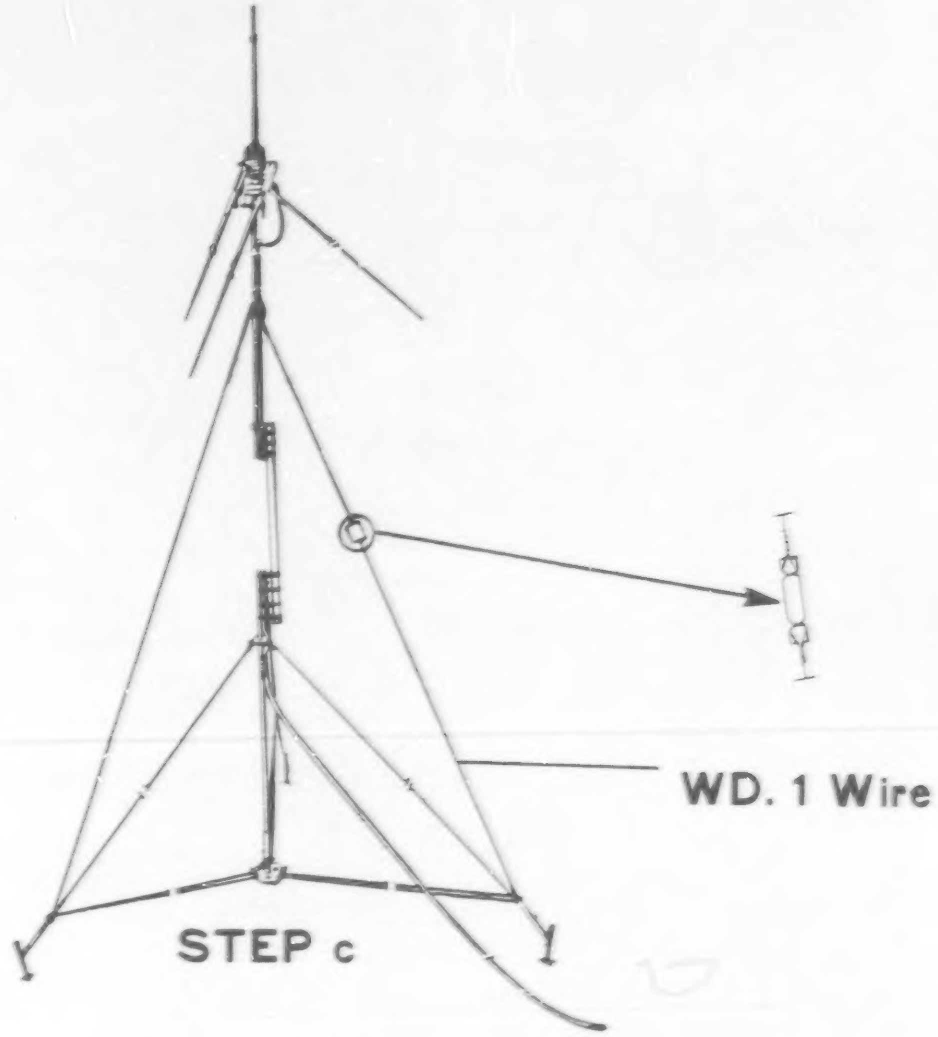


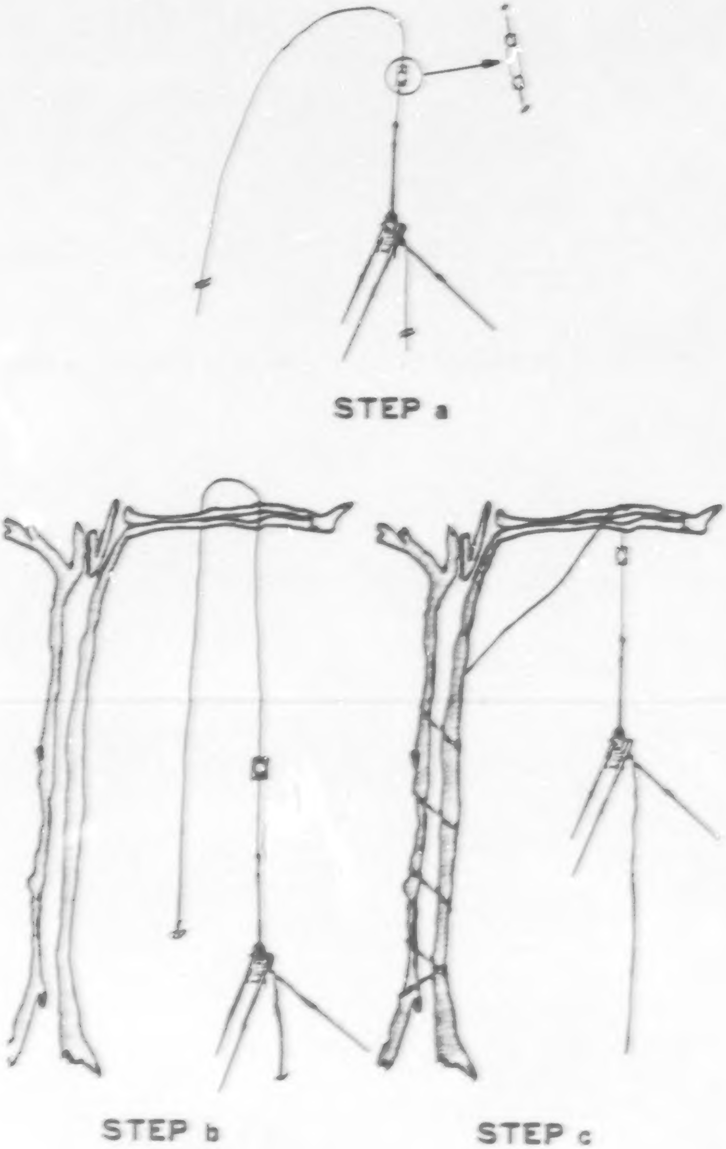
Fig AI-8. Mast section and guyline repair RC-292--continued.

(2) Tree supported RC-292. This ground plane is a regular RC-292 antenna without mast sections or guy lines (fig AI-9). Follow these simple steps for installation:

(a) Attach an insulator to the vertical element, and tie a piece of rope or wire to the other end of the insulator.

(b) Tie a weight on the other end of the rope, and throw the rope over a tree limb.

(c) Raise the antenna and tie off the rope.



STEP a

STEP b

STEP c

Fig AI-9. Tree support RC-292.

(3) Improvised (tree hung) RC-292. The tree hung (fig AI-10) can be a replacement for the RC-292 in any emergency. This improvised antenna can be used in wooded areas where a tree limb can be used to raise the antenna. Follow these steps when making this type of improvised RC-292:

(a) Using the quick reference chart at the end of this appendix or the formula for a 1/4-wave antenna, cut four wires for a 1/4-wave length each.

(b) Obtain three branches or slender sticks of wood.

(c) Position the three branches or sticks to form a triangle and tie the ends together.

(d) To each corner of the triangle, tie one end of each of the three 1/4-wave wires.

(e) Obtain an insulator and attach the other end's of the three wires to it.

(f) Attach the fourth 1/4-wave wire to the other end of the insulator.

(g) On the opposite end of the fourth 1/4-wave wire attach another insulator and to this insulator, attach a wire or rope which will be used to pull the antenna up into the air.

(h) Attach an antenna lead-in to the antenna as shown in figure AI-10 before raising the antenna. One end of the lead in is attached to the 1/4-wave vertical element and the other end to the three ground plan elements.

(i) Lastly, raise antenna and tie it off. Then attach the antenna lead-in to the antenna connector and radio chassis.

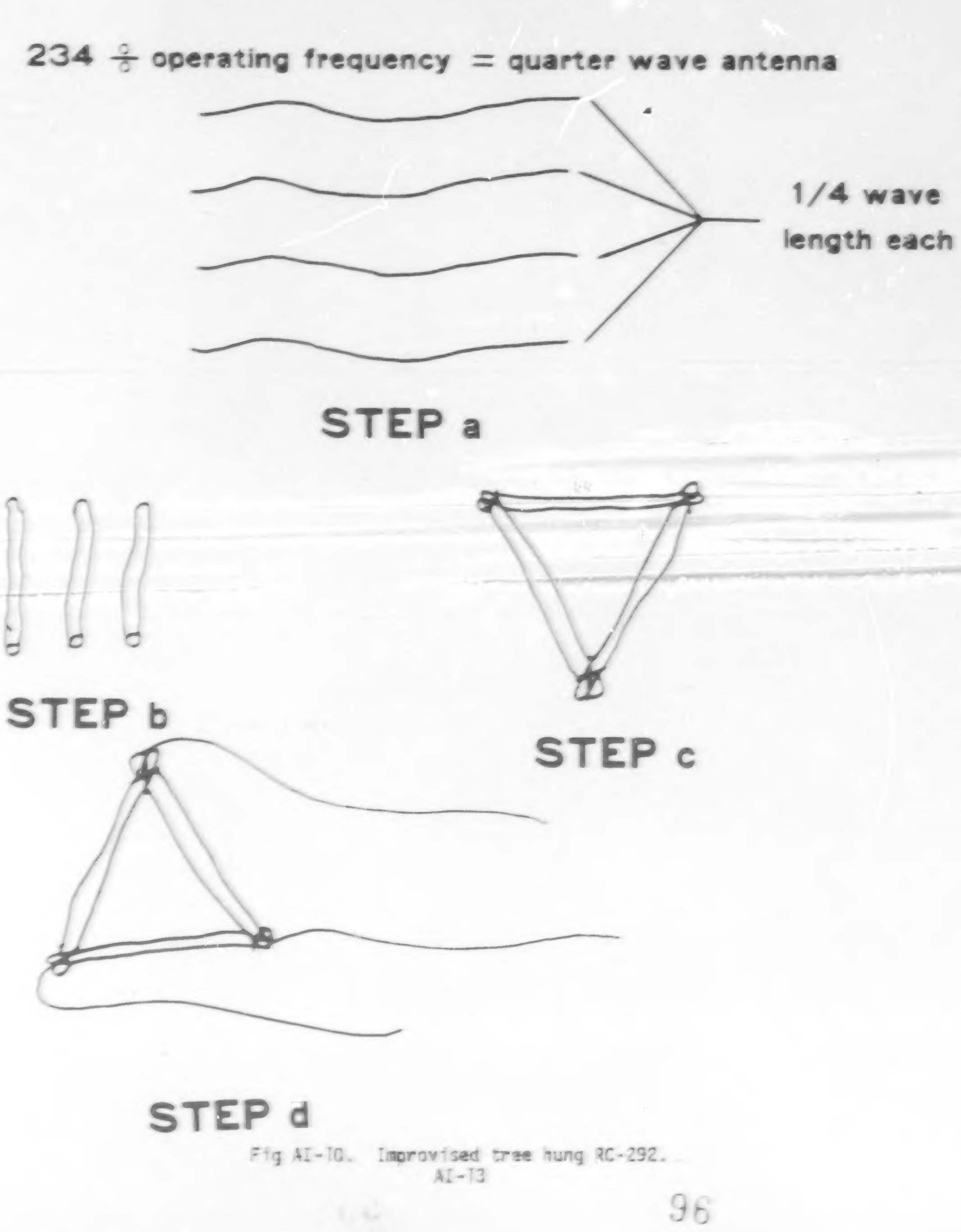
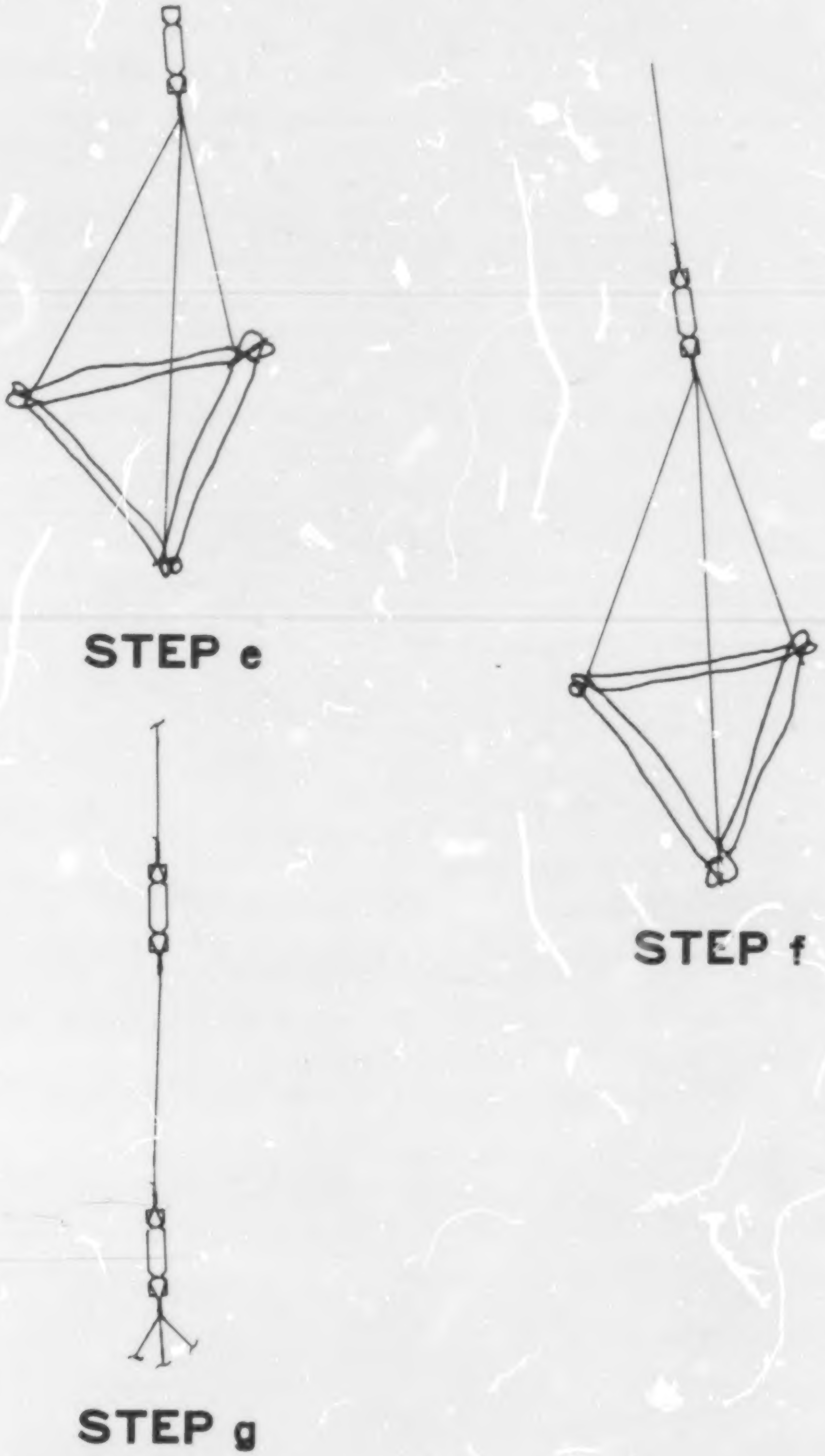

234 ÷ operating frequency = quarter wave antenna
1/4 wave length each
STEP a
STEP b
STEP c
STEP d

Fig AI-10. Improvised tree hung RC-292.

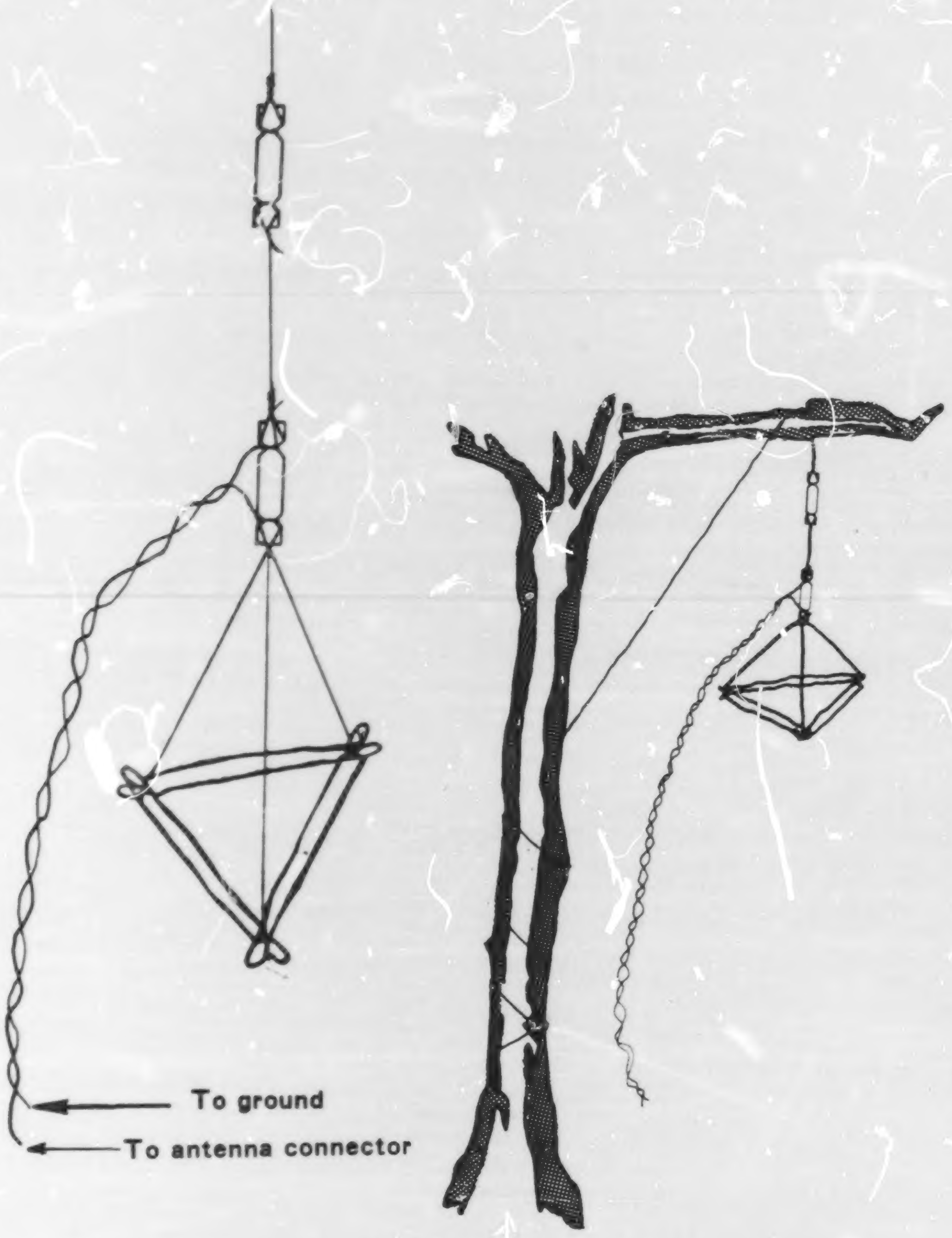


STEP e

STEP f

STEP g

Fig AI-10. Improvised tree hung RC 292--continued.


To ground
To antenna connector

STEP h

STEP i

Fig AI-10. Improvised tree hung RC-292--continued.

(4) Improvised ground plane (pole supported). This ground plane antenna (fig AI-11) can be used in areas where there are no trees to use as supports. It can be constructed as follows:

(a) Obtain a large pole.

(b) Compute and cut four wires for a quarter wave.

(c) Attach one quarter-wave wire (vertical element) to the pole (the exact location of wire on the pole will depend on antenna length.

(d) Attach the other three 1/4-wave wires (ground plane elements) to the pole. Ensure that they are insulated from the vertical element.

(e) Attach insulators to each of the ground plane elements and attach another wire to the opposite end of each insulator.

(f) Raise pole and tie down the three ground plane elements.

(g) Connect an antenna lead in the vertical and ground plane elements and to the antenna connector and radio ground.

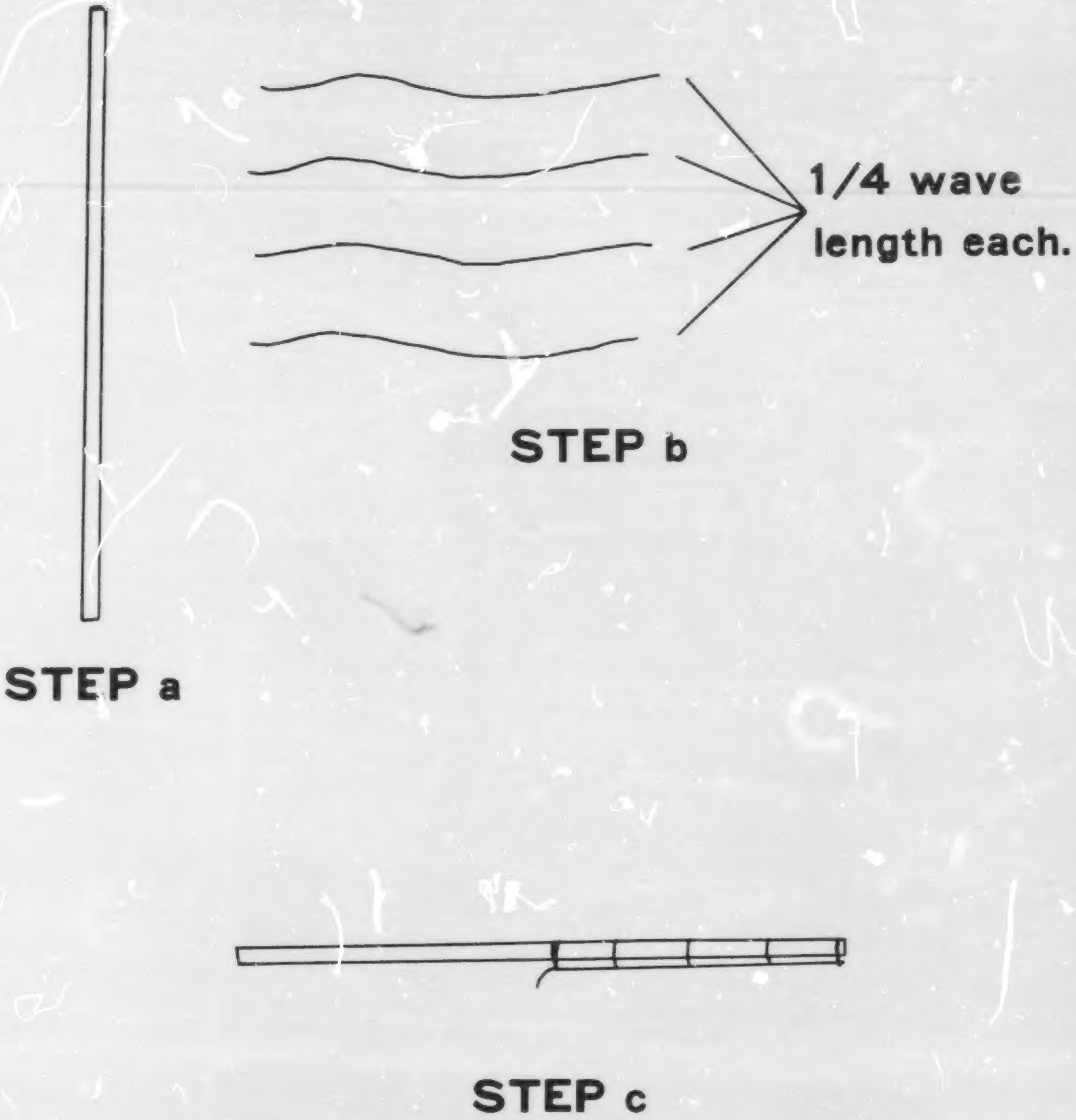
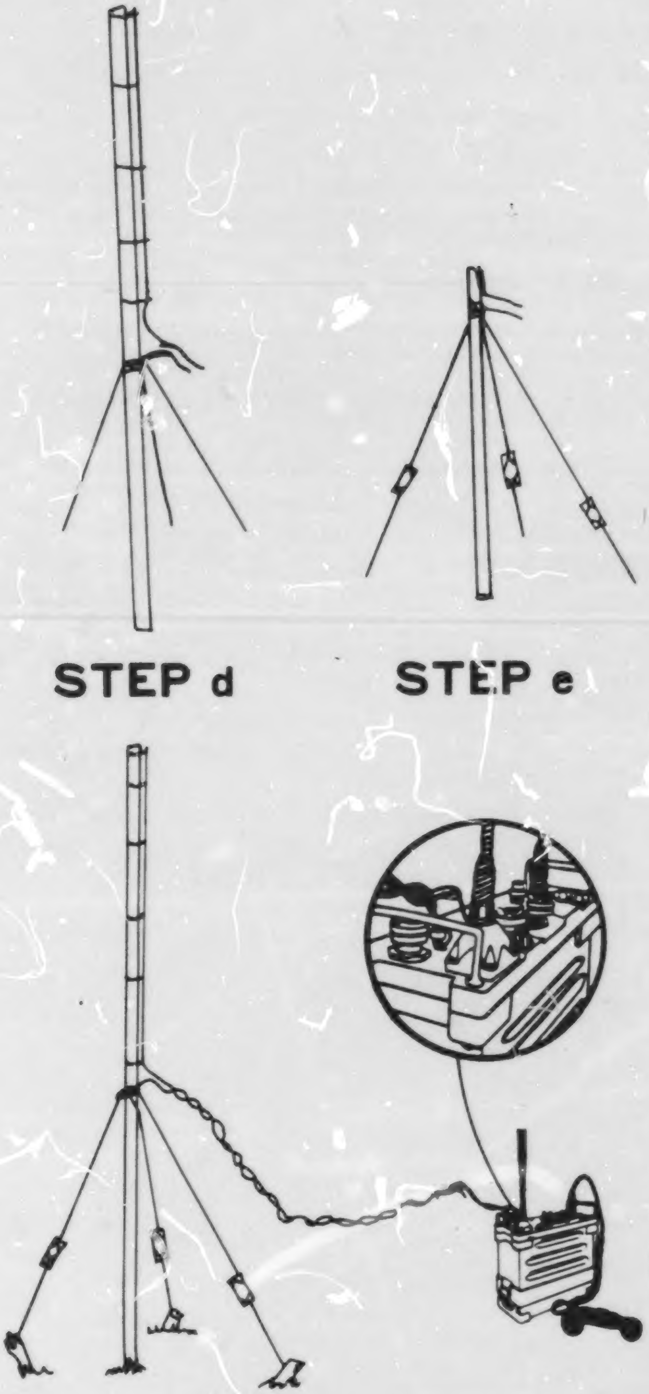


Fig AI-11. Improvised ground plane (pole supported) antenna.



STEP d

STEP e

STEP f,g

Fig AI-11. Improvised ground plane (pole supported) antenna--continued.

Bi-directional and Uni-Directional Antennas

a. One-half-wave Dipole. The Doublet or 1/2-wave dipole as it is more commonly called is a highly effective bi-directional antenna. It is normally used in the high frequency range, but can also be used effectively with radios that operate within the very-high-frequency range.

To construct the 1/2-wave dipole antenna, you will need the following items:

- Two supports (trees or poles)
- Wire (both for the antenna and halyards). Rope can also be used for the halyard.
- Three insulators

To build this effective antenna follow these simple steps:

(1) Cut the wire to your operating frequency using the chart or formula to compute the length needed for a half-wave antenna.

(2) Determine your direction of transmission because this type of antenna is bi-directional.

(3) Cut the wire in half and put an insulator on each wire end and one in the center.

(4) Locate and/or erect the two supports. Be certain they are 3 or 4 feet farther apart than the antenna's actual length and broadside to the direction of communications.

(5) Attach your antenna lead-in to both sides of the center insulator. Be sure that it is long enough to drop nearly to the ground and then to your radio's position.

(6) Tie ropes or wires to the two end insulators. Then, using whatever method is easiest, hang the antenna up between the supports and keep it as taut as possible.

(7) Connect one end of your antenna lead-in to the antenna connector and the other to a ground point on or near the radio.

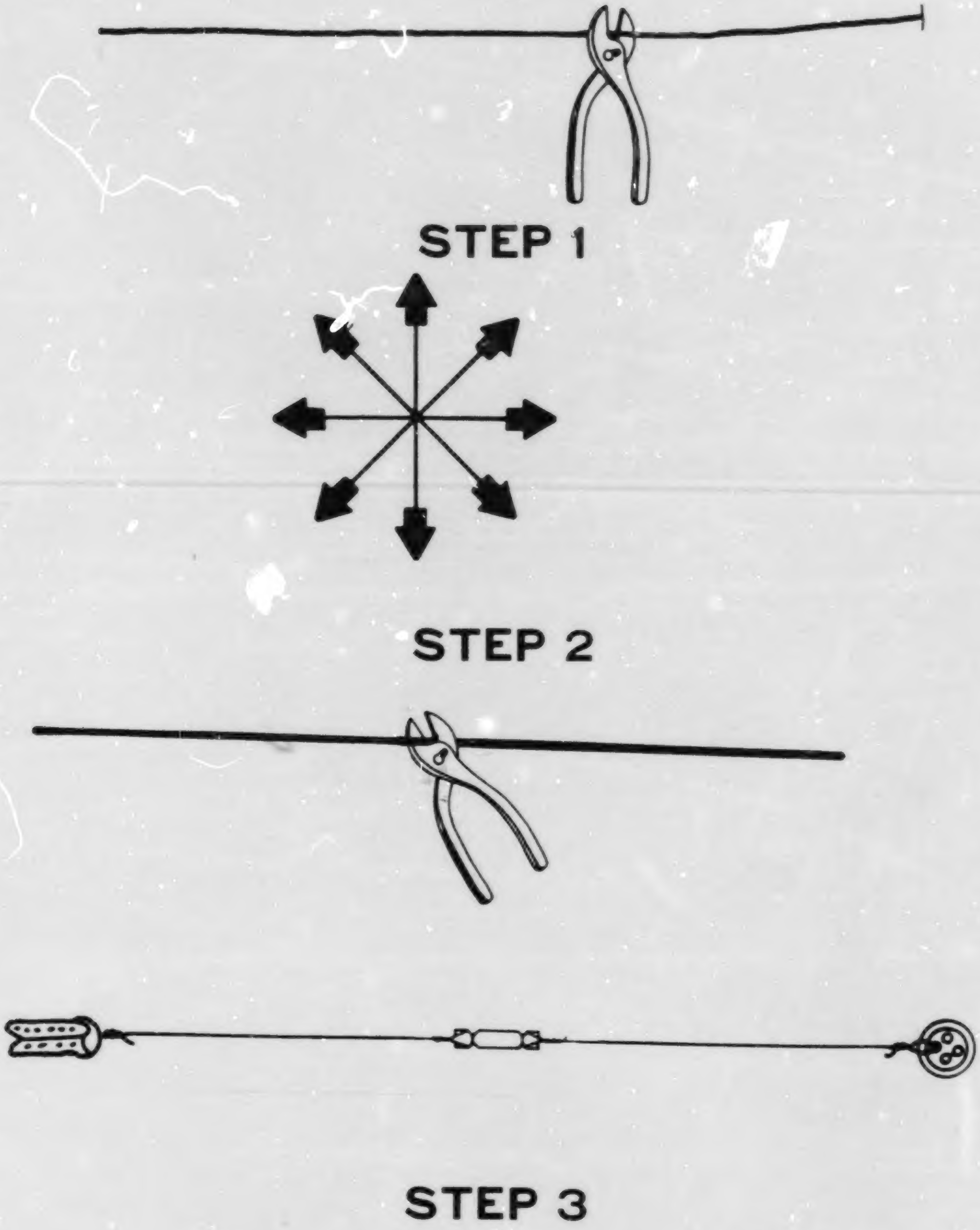
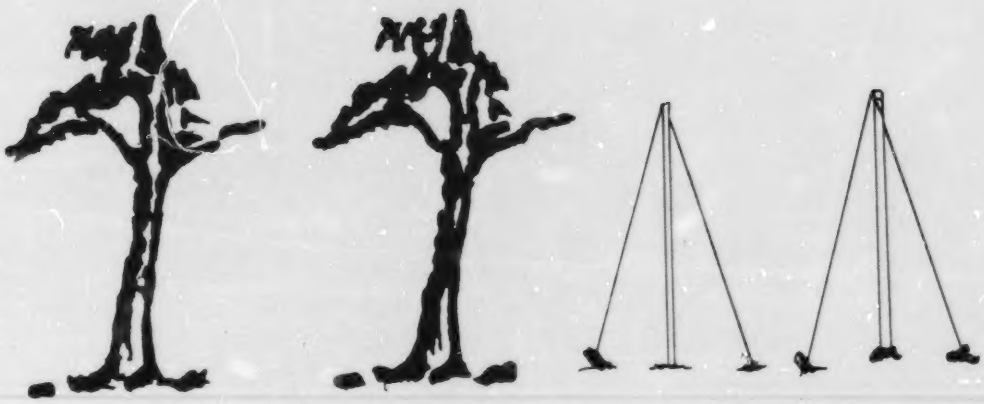
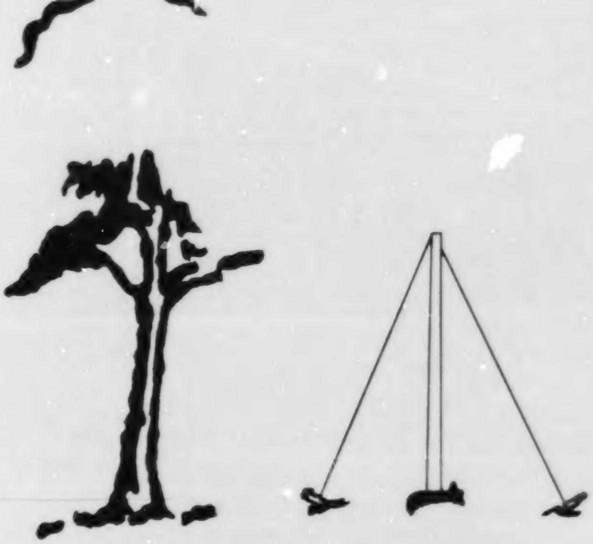

STEP 1
STEP 2
STEP 3

Fig AI-12. 1/2-Wave dipole antenna construction.

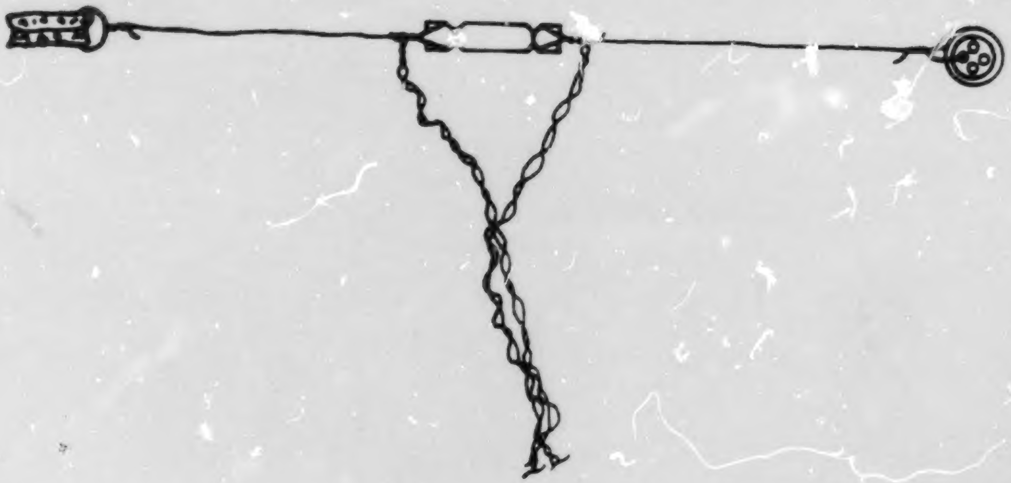


OR

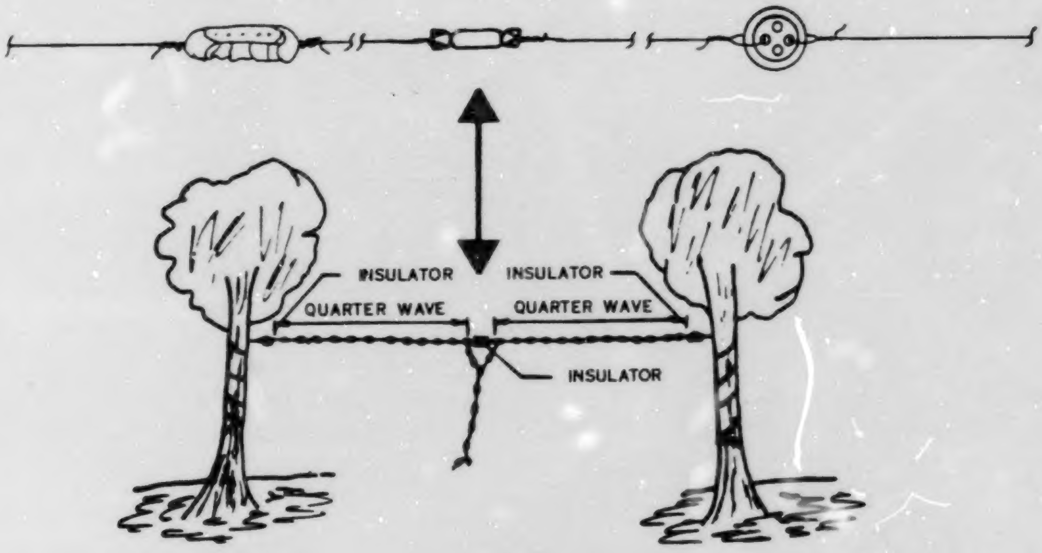


STEP 4

Fig AI-12. 1/2-Wave dipole antenna construction--continued.

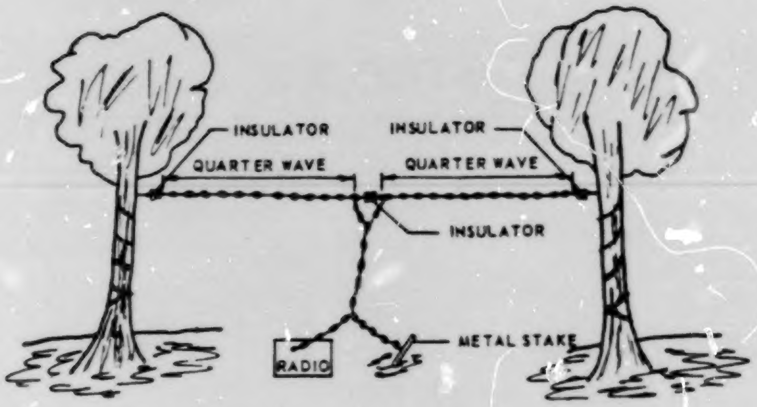


STEP 5


INSULATOR
INSULATOR
QUARTER WAVE
QUARTER WAVE
INSULATOR

STEP 6

Fig AI-12. 1/2-Wave dipole antenna construction--continued.


INSULATOR
INSULATOR
QUARTER WAVE
QUARTER WAVE
INSULATOR
RADIO
METAL STAKE

STEP 7

Fig AI-12. 1/2-Wave dipole antenna construction--continued.

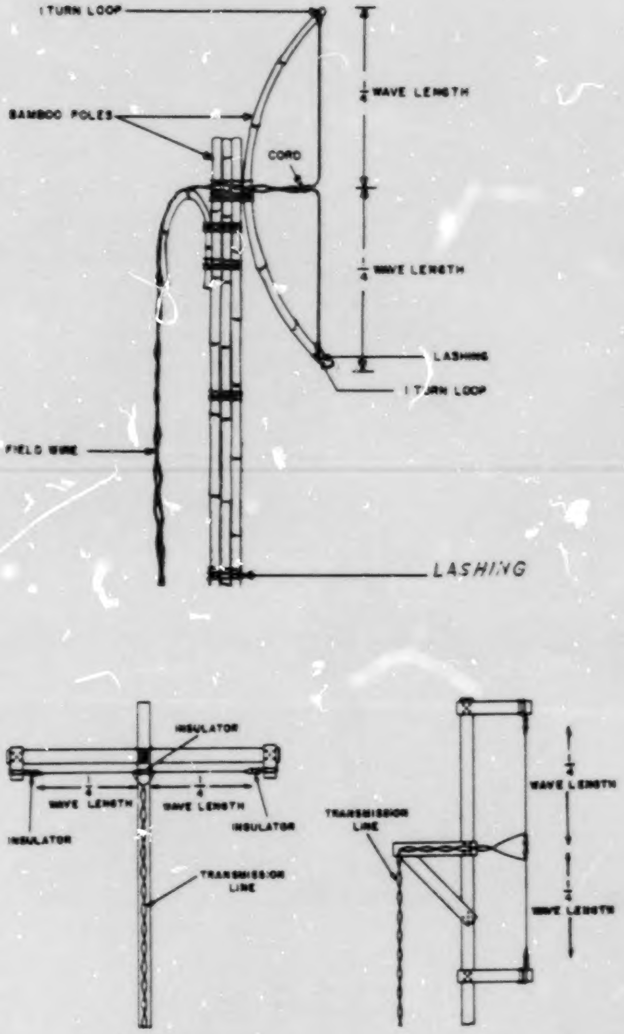

1 TURN LOOP
BAMBOO POLES
CORD
1/4 WAVE LENGTH
1/4 WAVE LENGTH
LASHING
1 TURN LOOP
FIELD WIRE
LASHING
INSULATOR
1/4 WAVE LENGTH
1/4 WAVE LENGTH
INSULATOR
INSULATOR
TRANSMISSION LINE
TRANSMISSION LINE
1/4 WAVE LENGTH
1/4 WAVE LENGTH

Fig AI-13. Improvised methods of supporting half-wave antennas.

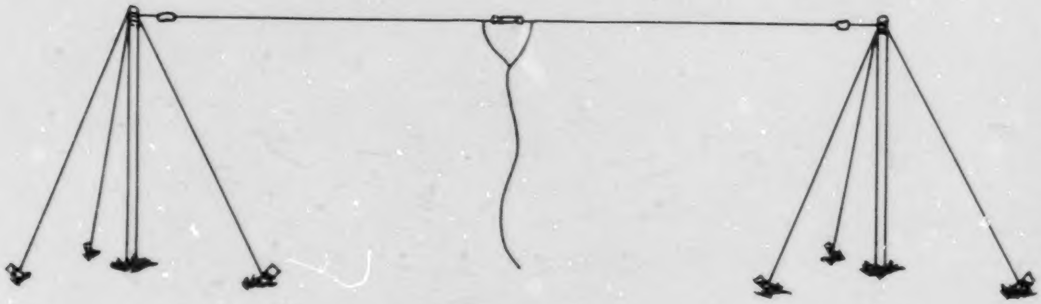
b. Two-Element Yagi Antenna. This configuration may be new to some communicators. As seen in figure I-12, it consists of a dipole modified by simply adding a reflecting element (a single wire) 1/4-wave length behind the dipole. This reflecting element will help increase the gain and make the antenna more directional. To construct this antenna, simply add the reflecting element as follows:

(1) Construct a 1/2-wave dipole.

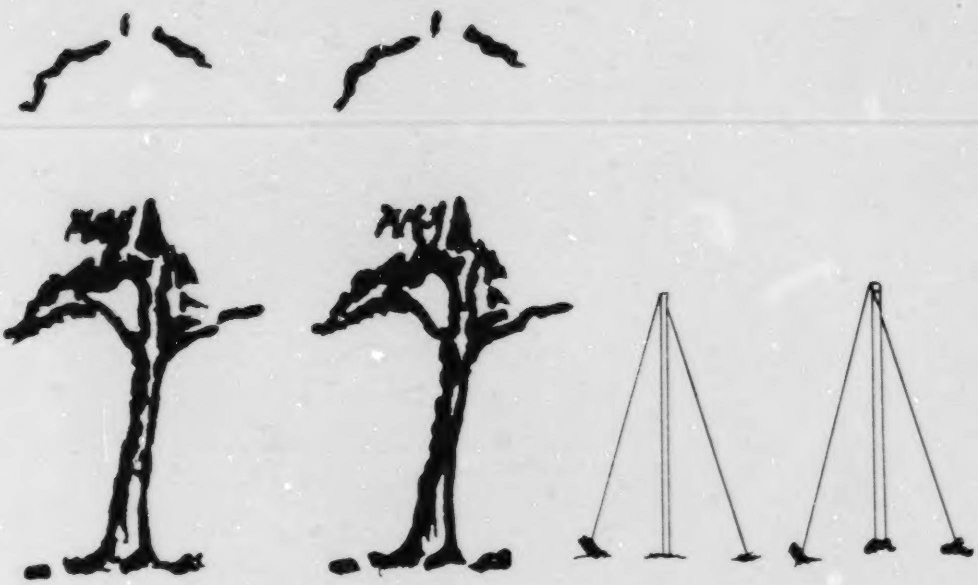
(2) Obtain two supports, either poles or trees.

(3) Cut reflecting element. Use L=468 divided by the operating frequency to obtain proper element length.

(4) Attach the reflecting element to the supports and erect the reflecting element 1/4-wave length behind the dipole antenna. Ensure out-station is forward of the antenna and reflecting elements.



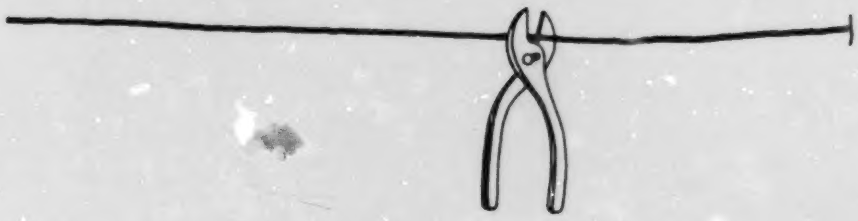
STEP 1



STEP 2

Fig AI-14. Two-element yagi antenna.

468 ÷ operating frequency = element length



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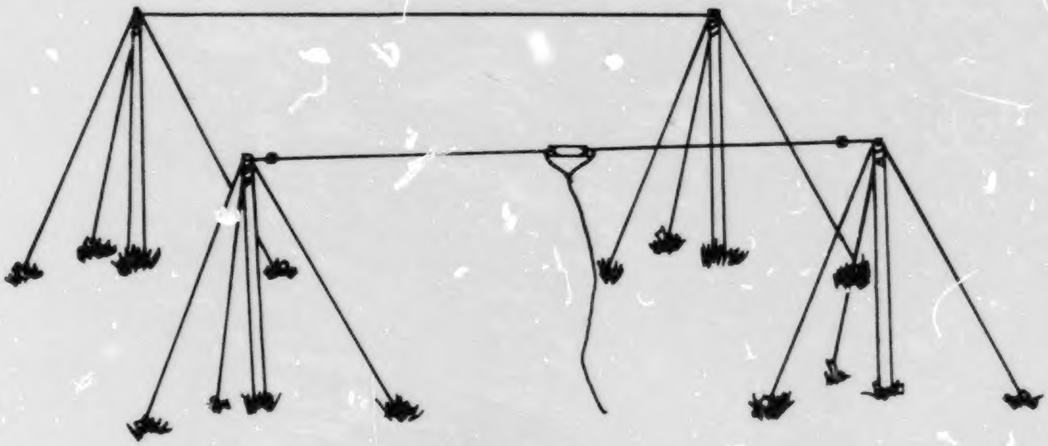


STEP 4

Fig AI-14. Two element yagi antenna--continued.

c. Long wire antenna. If you need more distance and directivity than your whip antenna will give you, try making a long wire antenna (fig 15). The overall length of the antenna must be between three to seven wave lengths of the operating frequency depending on the operating area and amount of construction material on hand. This antenna is bi-directional for high power VHF and HF, because in the field you won't be able to obtain a carbon resistor large enough to terminate the higher power radios. For low power VHF, this antenna is uni-directional when terminated with a 500 to 600 ohm, 2-watt carbon resistor. Make sure the antenna is set up for the direction you want to communicate because it is definitely not omni-directional. With this antenna you will find that you can communicate over longer distances in either one or two directions. Follow these simple steps when making a long wire antenna:

(1) Determine the direction of the station you need to reach and line up your antenna. Plan all your work in that direction.

(2) Cut antenna wire to the desired length. Use the quick reference chart at the end of this appendix or the formula for a full wave length antenna: 936 divided by operating frequency (936 must be multiplied by the desired antenna wavelength: i.e., three to seven wave length).

Example: 936 X 4 wavelengths = 3744,
3744 divided by operating frequency = length

Example: 3744 divided by 30 MHz = antenna length of 124 feet, 8 inches.

(3) Select the two supports which will hold up your antenna. The length or height of available supports will depend on the operating area. If you're operating in a forested area, trees may be used as supports, and the higher off the ground the better. If operating in a desert environment, tent or PO-2 poles may be your only choice, so use whatever is available. Remember, the higher off the ground the better.

(4) Attach the antenna wire to the two supports.

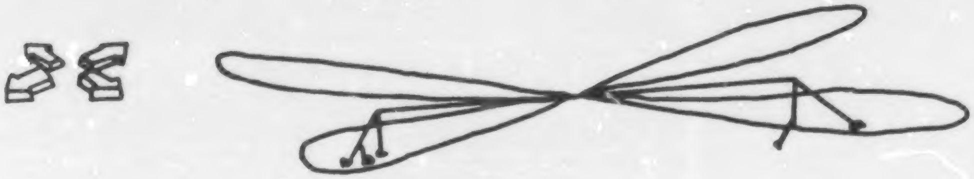
(5) Attach an insulator to each end of the antenna wire.

(6) Connect tiedown wires outside the insulators on each end of the antenna wire.

(7) Raise and tie down the antenna.

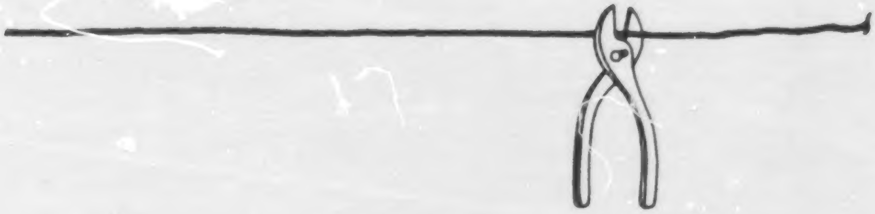
(8) Connect antenna lead-in to the antenna and radio set.

(9) Connect resistor to the far end of antenna, if desired.



STEP 1

936 + OPERATING FREQUENCY × 3 TO 7 WAVE LENGTHS = ANTENNA LENGTH IN FEET AND INCHES.



STEP 2

Fig AI-15. Long wire antenna construction.

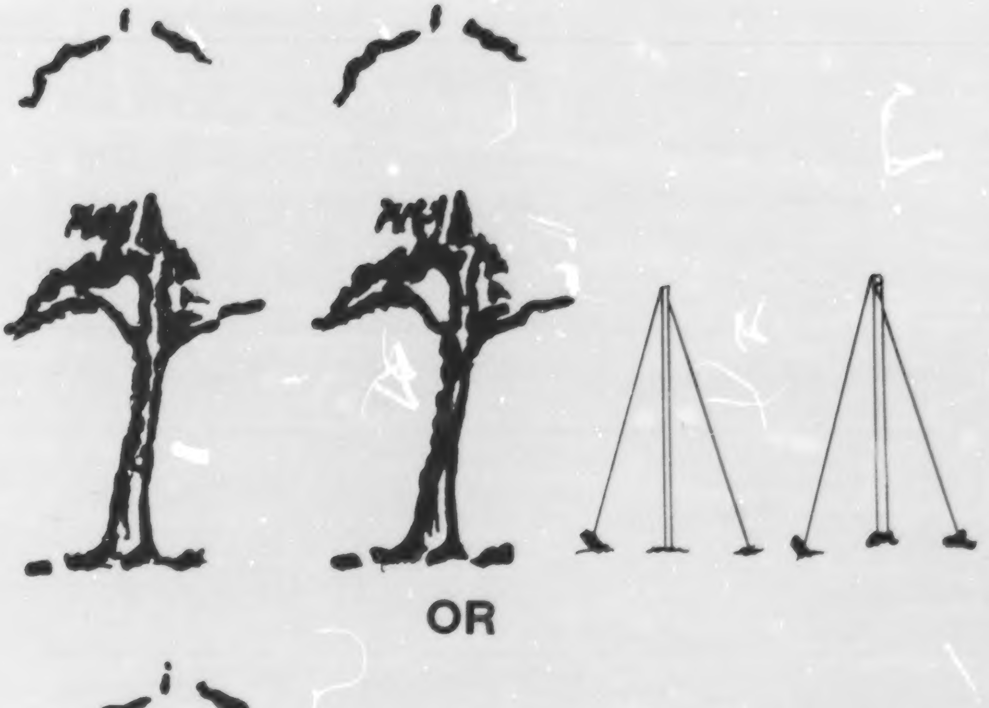
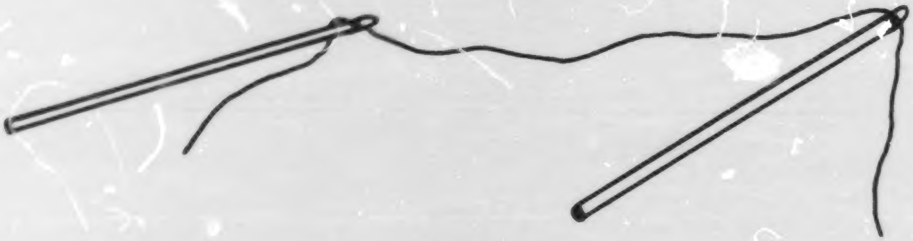
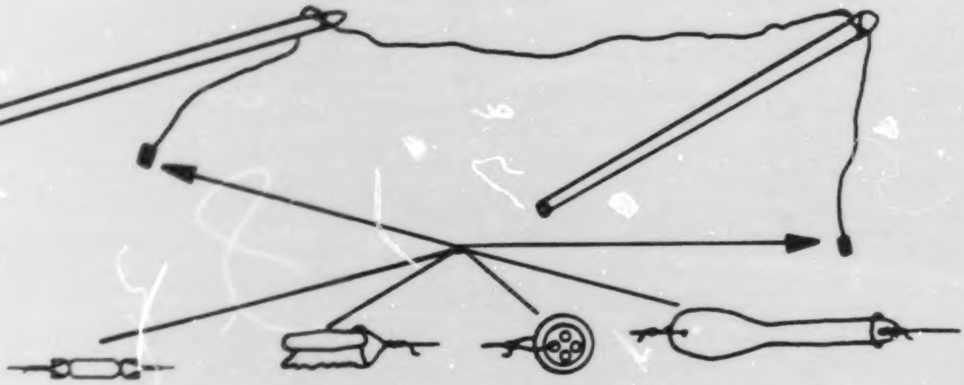


Fig AI-15. Long wire antenna construction--continued.



STEP 4



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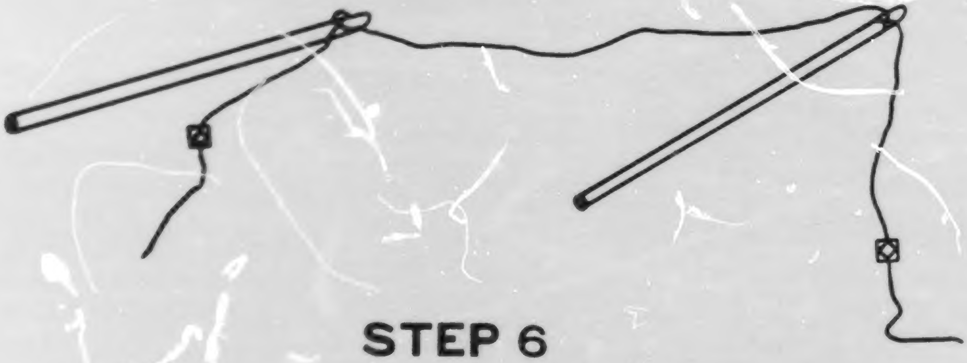
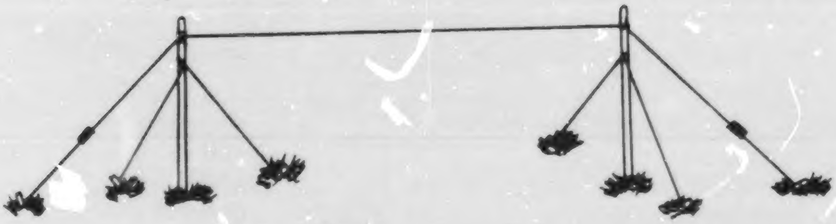


STEP 6

Fig AI-15. Long wire antenna construction--continued.



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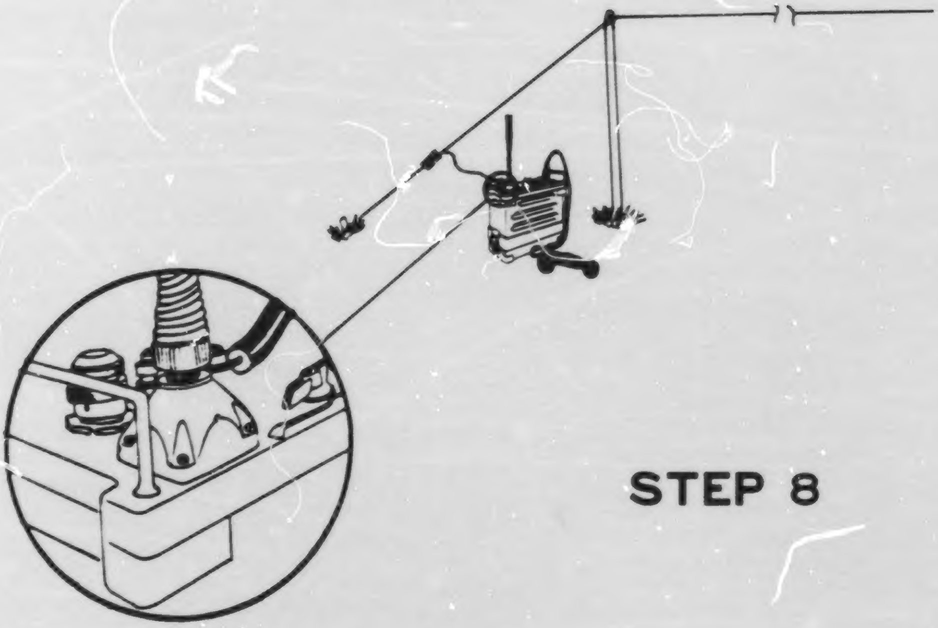
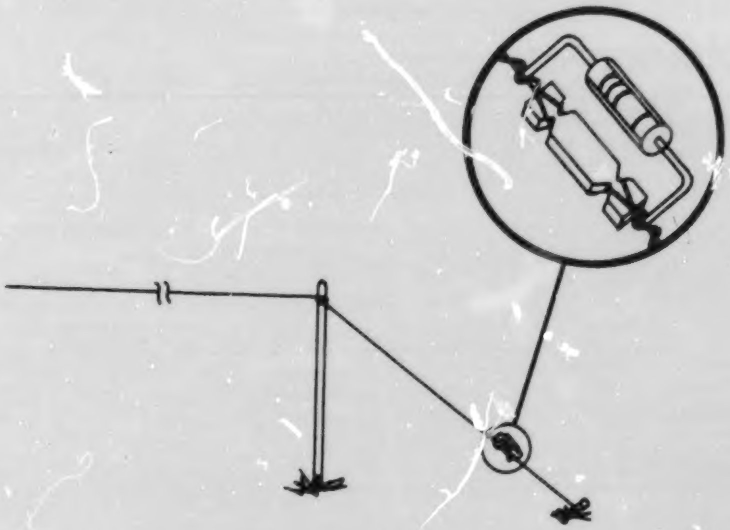


STEP 8

Fig AI-15. Long wire antenna construction--continued.



STEP 9

Fig AI-15. Long wire antenna construction--continued.

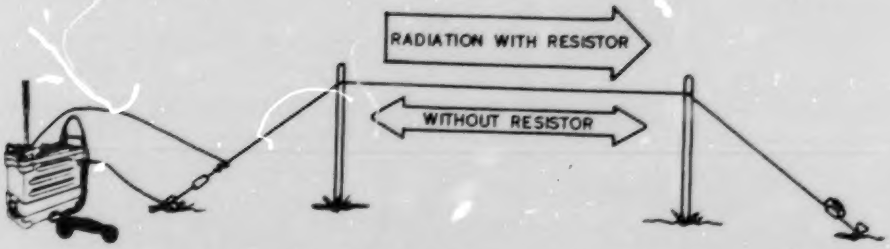


Fig A1-15. Long wire antenna construction--continued.

d. Sloping V antenna. The Sloping V antenna consists of two long wires arranged to form a V which slopes down towards the ground. It is bi-directional to uni-directional and produces primarily sky waves. The following steps show you how to construct one:

(1) Determine the direction of the station you need to reach and line up your antenna. Plan all your work in that direction.

(2) Cut wire for the antenna legs. Leg length is noncritical, but should be at least two wavelengths long. Antenna wire should be of number 10 to 16 copper clad wire.

(3) Connect insulators to each end of the antenna legs. Add tie down wires to the opposite ends of each insulator.

(4) Select a tree or pole to serve as a mast for the antenna.

(5) Connect antenna legs to mast, select apex angle depending upon antenna leg length, in wavelengths.

(6) Extend the antenna legs out and stake them down to metal stakes.

(7) Attach a balanced transmission line to the antenna legs, and radio set.

(8) To make the antenna more directional, simply connect noninductive resistors between the open end of each leg of the antenna. The resistors should be between 400 and 800 ohms (typically 500 ohms), and each should be capable of dissipating up to half of the transmitter power.

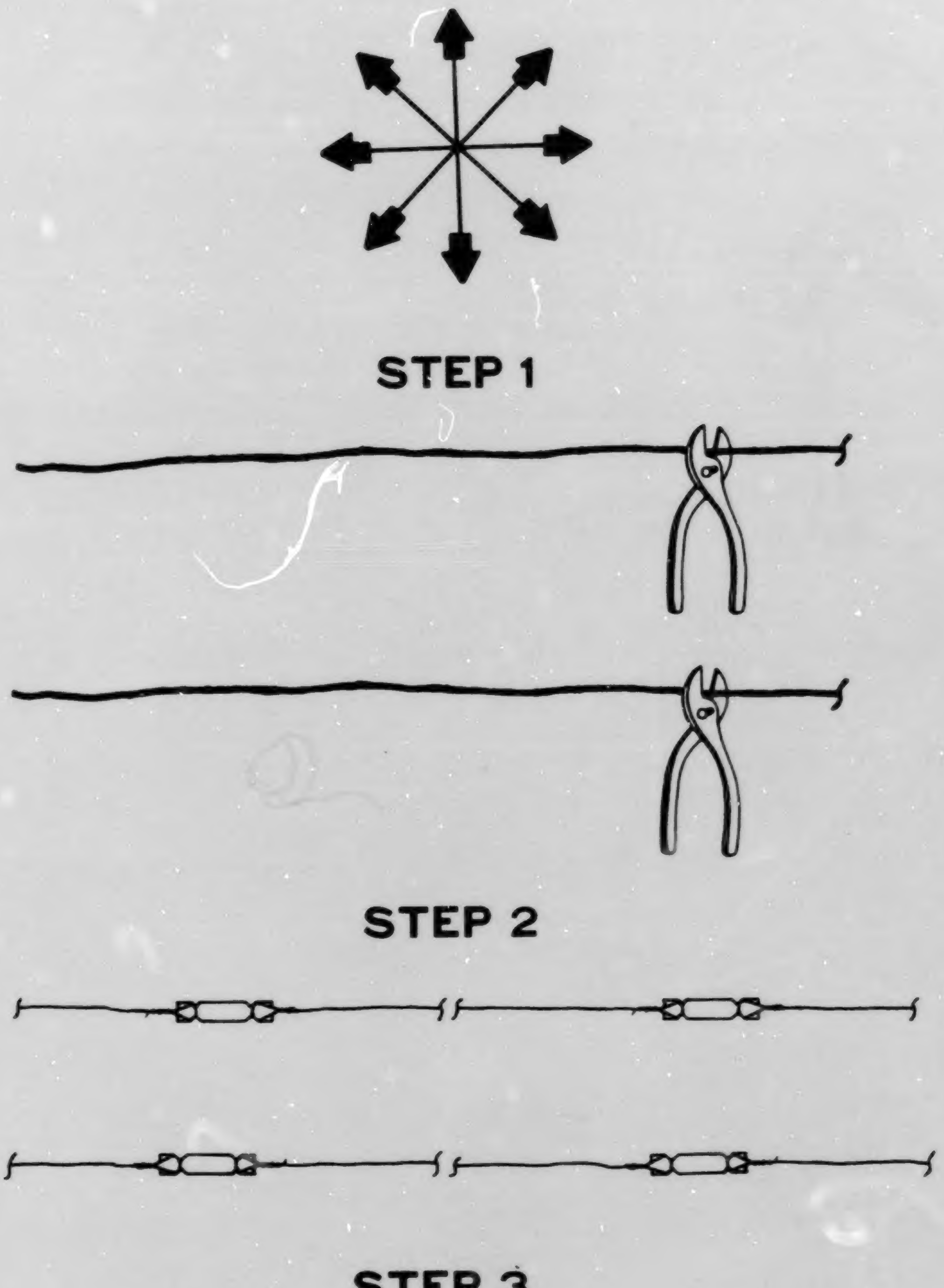
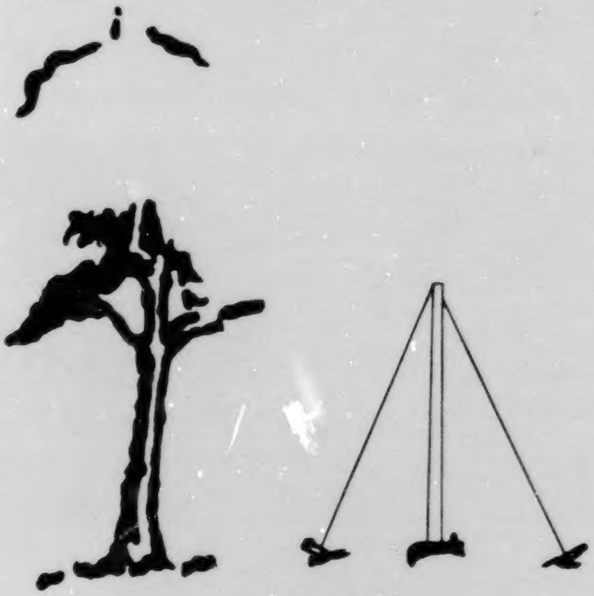

STEP 1
STEP 2
STEP 3

Fig AI-16. Sloping V antenna construction.



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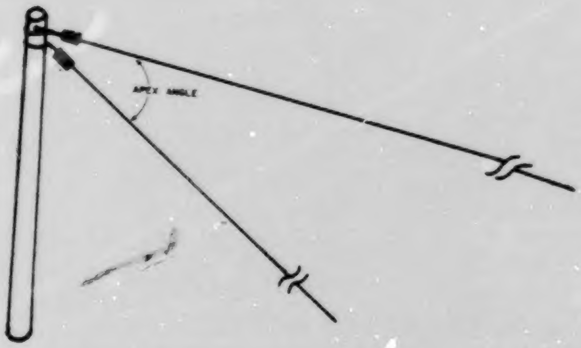
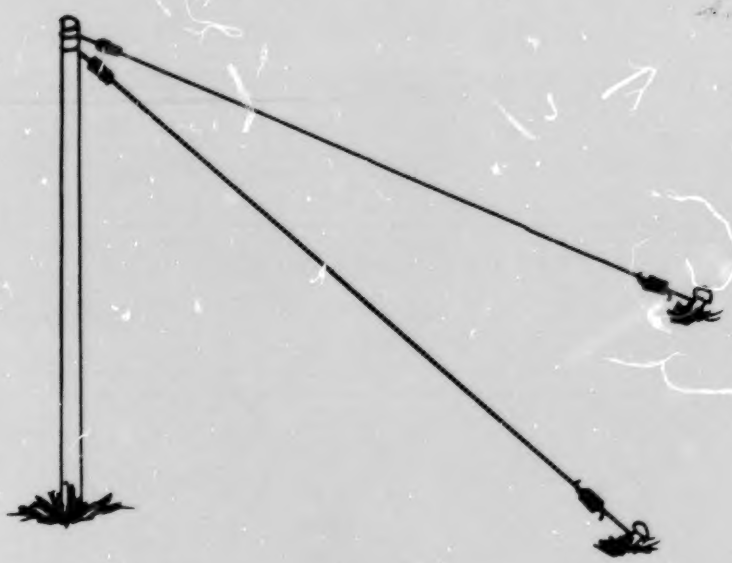


Antenna Length (wavelengths)	Optimum Apex Angle (degrees)	Antenna Length (wavelengths)	Optimum Apex Angle (degrees)
1	90	6	40
2	70	8	35
3	58	10	33
4	50		

STEP 5

Fig AI-16. Sloping V antenna construction--continued.



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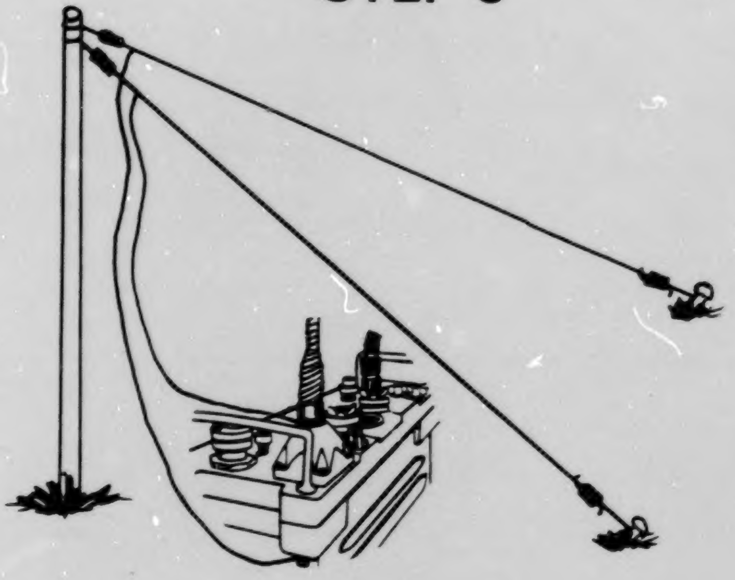
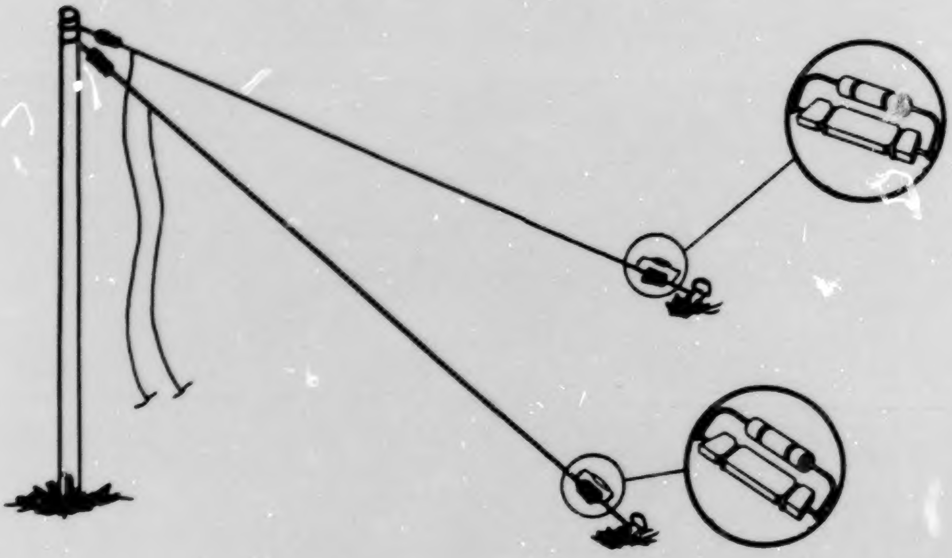


STEP 7

Fig 16. Sloping V antenna construction--continued.



STEP 8

Fig 16. Sloping V antenna construction--continued.

e. Vertical Half-Rhombic. The half-rhombic antenna is a terminated vertical antenna. An unbalanced transmission line is used along with a ground or counterpoise for this type of antenna. This longwire antenna will give you more distance and directivity over whip type antennas. The vertical half-rhombic is a fairly simple antenna to construct, just follow these simple steps:

(1) Determine the direction of the station you need to reach and line up your antenna. Plan all your work in that direction.

(2) Cut the antenna wire. Wire length will depend on the operating frequency and the size of the available site. Each leg of the antenna should be at least one wave length long. At 30 MHz the leg wave length is 1 1/2 wavelength and at 70 MHz it is 3 1/2 wavelengths.

(3) Connect an insulator to each end of the antenna wire. Add tie down wires to each insulator.

(4) Select a middle support, either a tree, pole, or a wire or rope suspended between two poles or structures. Support should be between 20-30 feet high. Preferably 30 feet or higher.

(5) Select one end of the antenna wire with insulator, tie it down and run it out toward the station you need to communicate with and stake it down on a metal stake.

(6) Connect or hang antenna wire on or over the support and raise antenna.

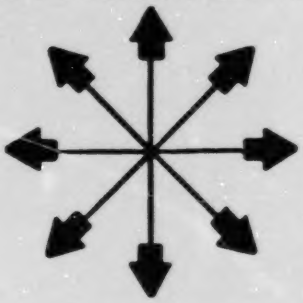
(7) Extend the other end of the antenna wire until it is tight and stake it down using another metal stake.

(8) Obtain, measure and cut another piece of wire to be used as a counterpoise.

(9) Attach one end of the counterpoise between the ground stake and antenna insulators. Then run the counterpoise to the other end of the antenna keeping it a foot off the ground. Attach the counterpoise between ground stake and antenna insulator.

(10) Attach an antenna lead-in to antenna and radio.

(11) To make this antenna more directional, connect a 500-to 600-ohm, 1-to 2-watt carbon resistor across the insulators at the far end.



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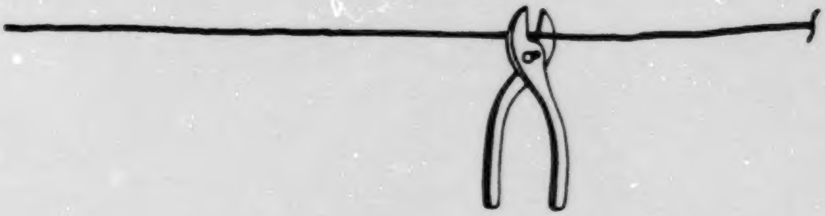

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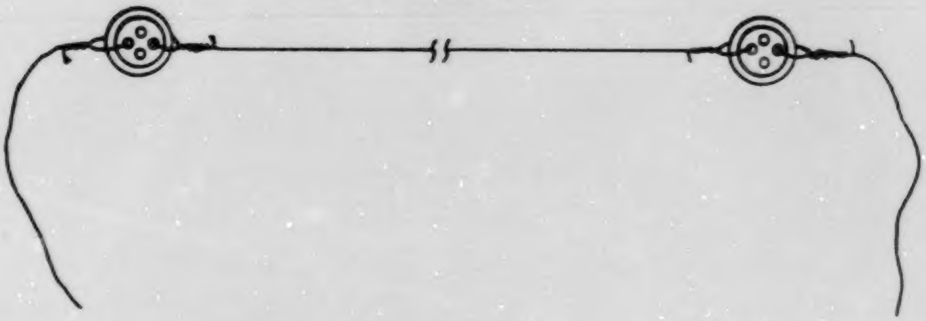
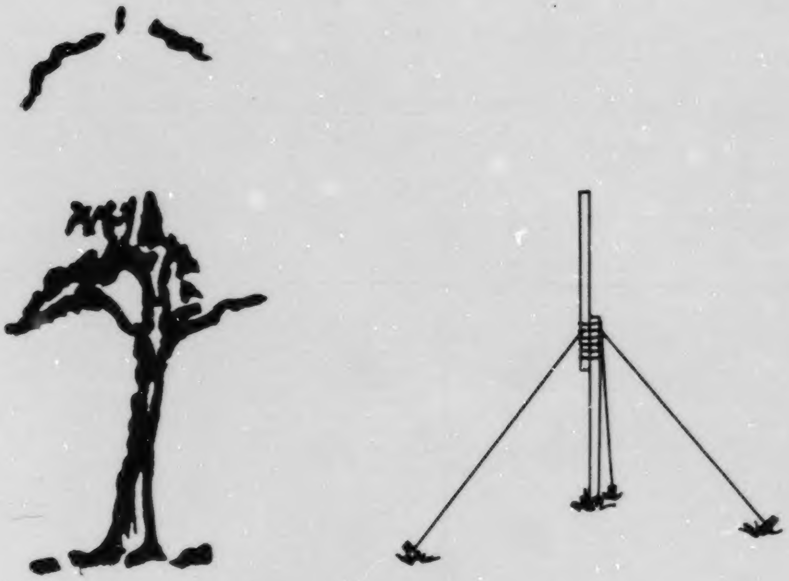


STEP 3

Fig AI-17. Half-rhombic antenna construction.



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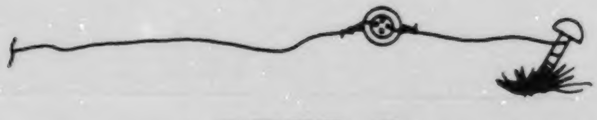
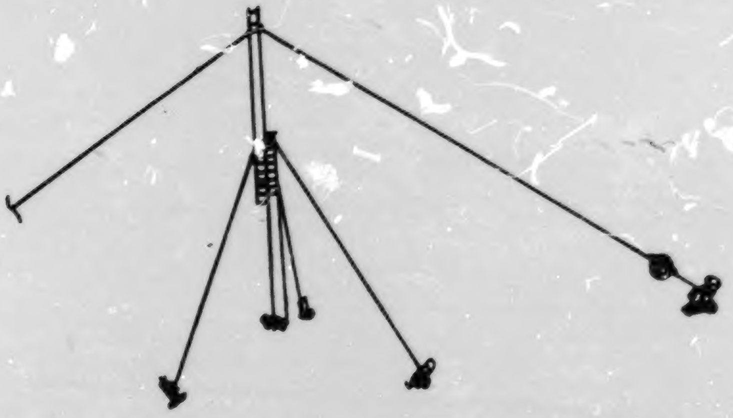


STEP 5

Fig AI-17. Half-rhombic antenna construction--continued.



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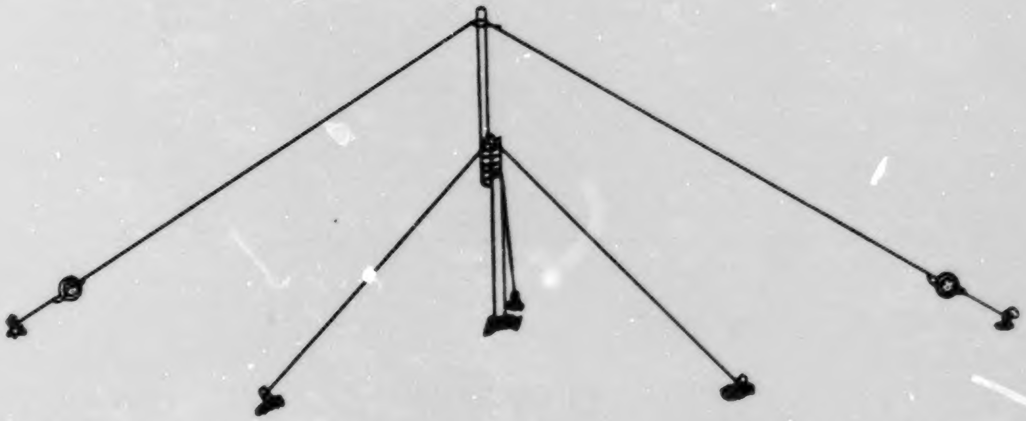
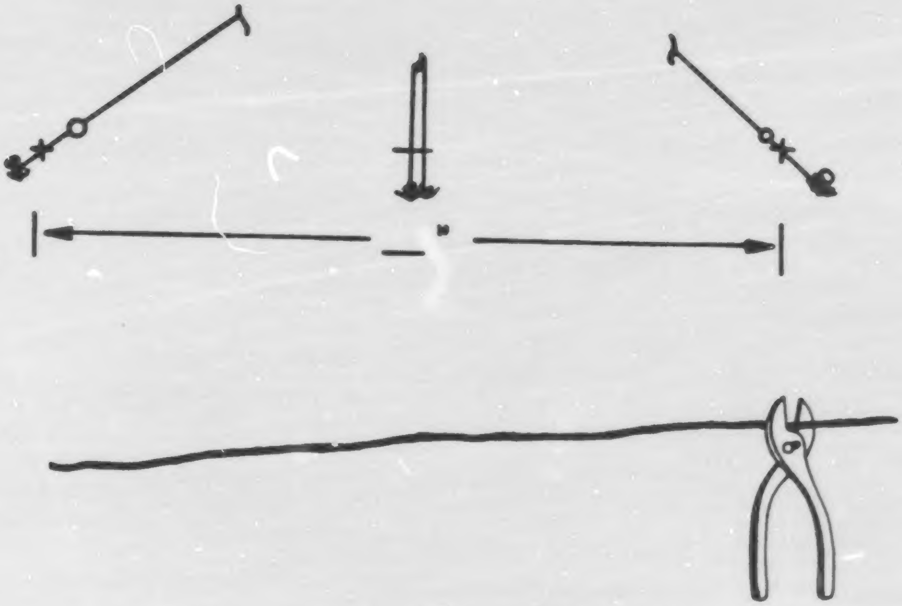


STEP 7

Fig AI-17. Half-rhombic antenna construction--continued.



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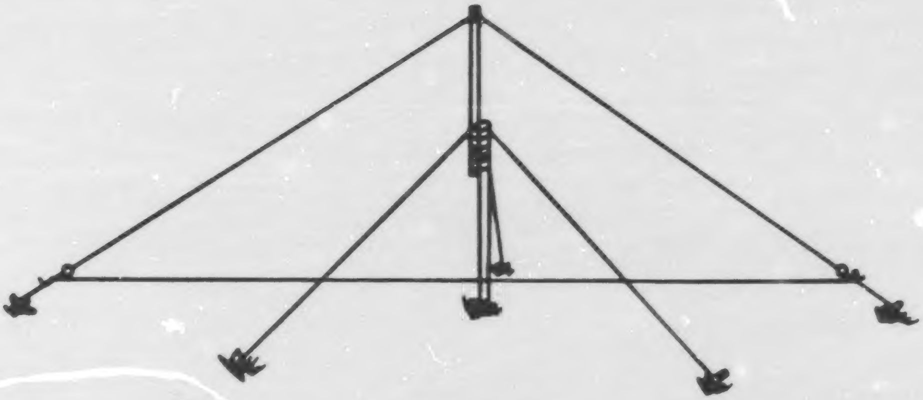
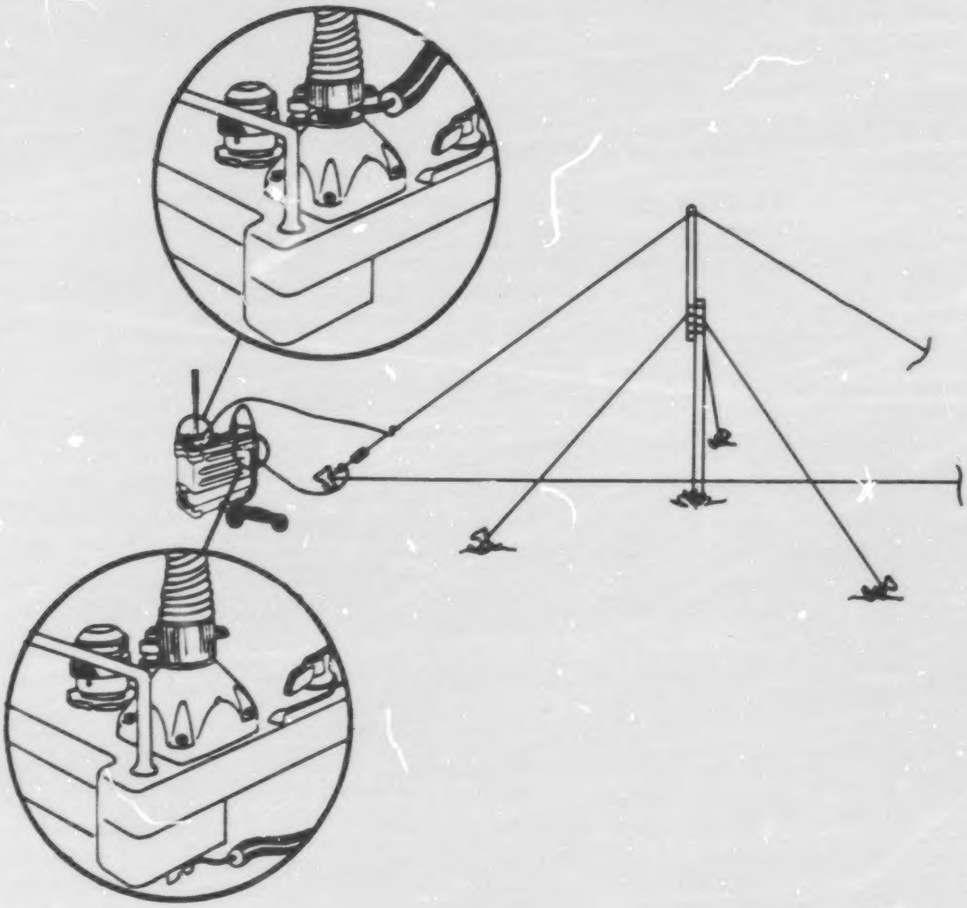
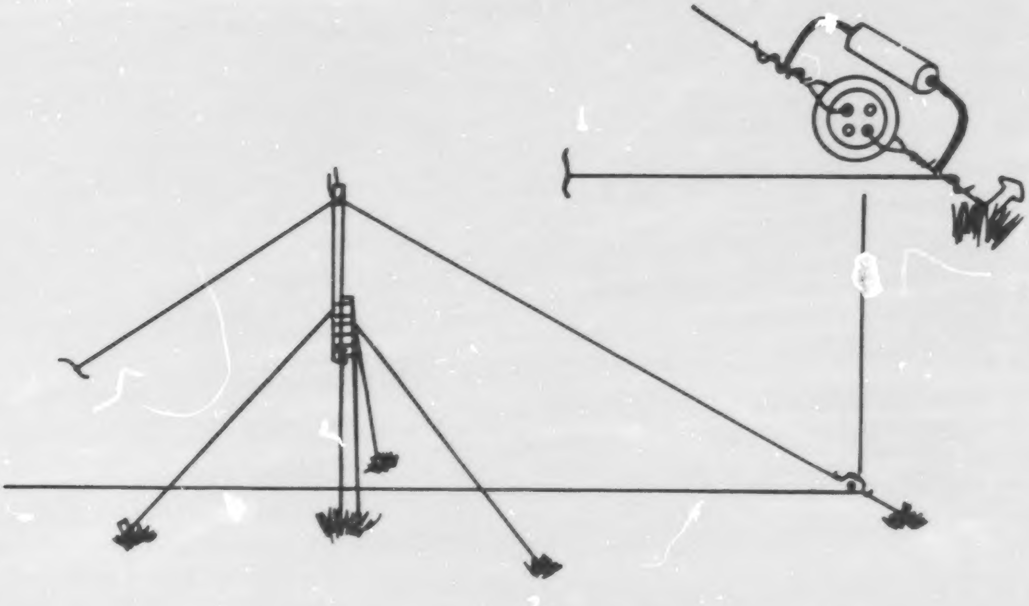


STEP 9

Fig AI-17. Half-rhombic antenna construction--continued.



STEP 10



STEP 11

Fig AI-17. Half-rhombic antenna construction--continued.

Formulas and HF/VHF Quick Reference Charts

You can determine the length of the antenna you need by using the proper formula below or the proper quick reference chart.

To figure a quarter-wavelength antenna in feet: Divide 234 (constant) by your operating frequency in MHz example: 234 divided by 44.8 = 5.22 or 5'2"

To figure a half-wavelength antenna in feet: Divide 468 (constant) by your operating frequency in MHz example: 468 divided by 56 = 8.36 or 8'5"

To figure a full-wavelength antenna in feet: Divide 936 (constant) by your operating frequency in MHz example: 936 divided by 45 = 20.8 or 20'10"

To convert feet to meters, multiply by .3048 (constant) example: 110 feet X .3048 - 33.5 meters

To convert meters to feet multiply by 3.28 (constant) example: 100 meters X 3.28 = 328

Table AI-1. HF/VHF Quick Reference Chart

High Frequency (HF) Antenna Length in Feet & Inches				Very High Frequency (VHF) Antenna Length in Feet & Inches			
Op Freq in MHZ	1/4 Wave	1/2 Wave	1 Wave	Op Freq in MHZ	1/4 Wave	1/2 Wave	1 Wave
2	117'	234'	468'	30	7'10"	15'7"	31'2"
3	78'	156'	312'	33	7'1"	14.2"	28'4"
4	58'6"	117'	234'	35	6'9"	13'5"	26'10"
5	46'9"	93'7"	187'4"	37	6'4"	12'7"	25'2"
6	39'	78'	156'	40	5'10"	11'8"	23'4"
7	33'5"	66'10"	133'8"	43	5'5"	10'10"	21'8"
8	29'3"	58'6"	117'	45	5'3"	10'5"	20'10"
9	26'	52'	104'	48	4'10"	9'8"	19'4"
10	23'5"	46'10"	93'8"	50	4'9"	9'5"	18'10"
11	21'3"	42'6"	85'	55	4'3"	8'6"	17'
12	19'6"	39'	78'	57	4'1"	8'2"	16'4"
13	18'	36'	72'	60	3'11"	7'10"	15'8"
14	16'9"	33'5"	66'10"	65	3'7"	7'2"	14'4"
15	15'7"	31'2"	62'4"	68	3'5"	6'10"	13'8"
16	14'7"	29'2"	58'4"	70	3'4"	6'7"	13'2"
17	13'9"	27'6"	55'	75	3'1"	6'2"	12'4"
18	13'	26'	52'	80	3'	5'11"	11'10"

Field Expedient Insulators

Materials which are made up of nonconducting substances like porcelain, glass, rubber and plastic are used in antenna system construction to prevent undesired current flow paths or short circuits in the system. Examples of some very common items readily available for use as insulators for field expedient antenna systems are buttons, bottle necks, tire tubes and dry cloth or rope.

Figure AI-18 below shows how these items may be used.

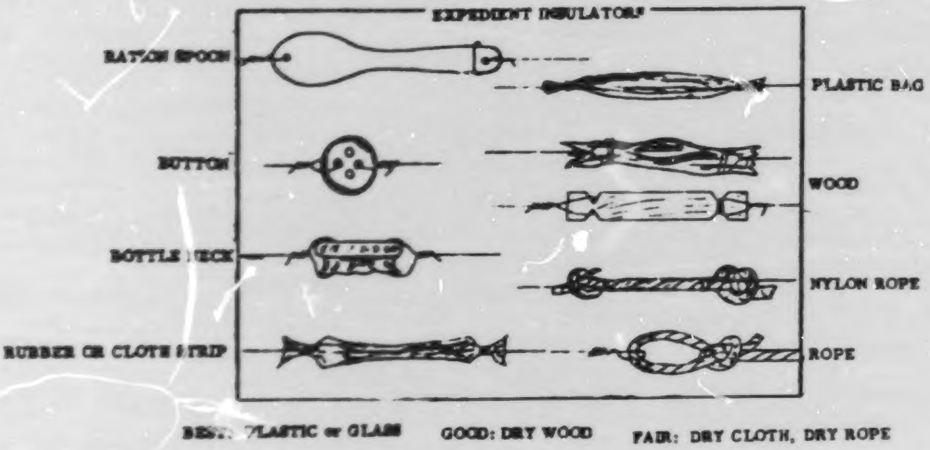

EXPEDIENT INSULATORS
RATION SPOON
BUTTON
BOTTLE NECK
RUBBER OR CLOTH STRIP
PLASTIC BAG
WOOD
NYLON ROPE
ROPE
BEST: PLASTIC or GLASS
GOOD: DRY WOOD
FAIR: DRY CLOTH, DRY ROPE

Fig AI-18. Field expendient insulators.

Table AI-2. Field Expedient Items

Here are some field expedient items that might help you get the job done in an emergency.

Original issue	Field expedient
Antenna wire	WD-1, barbed wire, electrical wire, coaxial cable
Antenna mast	Trees, sticks, lance pole, telephone pole
Coaxial cable	WD-1, electrical wire
Antenna guy rope	Wire, cloth belts
Guy Stakes	Rocks, vehicles, trees, tent pins
Whip antenna	Wire, WD-1, coaxial cable
Pulleys	Wire, nylon rope
Insulators	Plastic rings, spoons, and bags, wood, rope, rags and bottles.

Table AI-3. Field Tool Kit

The following is a list of tools and equipment which will aid in the construction and erection of field antennas.

1 each	Large screwdriver set with sizes of flat blade screwdriver blades, 1 Phillips blade and 1 awl stored in handle.
1 each	Small screwdriver set, jeweler's size, similar to above item.
1 each	Longnose pliers.
1 each	Pliers.
1 each	Miniature flashlight using 1 size AA cell, with 2 spare bulbs.
1 each	Nickel-cadmium AA cell.
1 each	Cleaning brush, electric shaver type.
1 each	Compass, button type.
1 each	Magnifying glass.
3 each	Oil capsule, clear color.
8 each	Stick pins, for use with indoor antennas.
1 each	Eraser.
1 each	Cleaning cloth.
2 each	Plastic electrical tape stripe.
2 each	Pipe cleaners.
1 each	Aluminum foil, 6 x 6 inches, for jumping fuses.
10m	Receiving antenna wire.
1 each	Key, socket head screw; c/o 11 hex short arm keys. (Allen wrench)
1 each	Tweezers, Craftsman.
1 each	Wrench, open-end.
1 each	Pen-knife.
1 each	Dikes (wire cutter).
1 each	Drill (hand).
1 each	Soldering torch (pocket type).
1 each	Solder (small spool).
1 box	Metal screws #4.
1 box	Machine screws #4-40.
1 box	Nuts #4.
1 box	Washers #4.
1 box	Solder Lugs #4.

Table AI-3. Field Tool Kit--continued

1 box	Nails.
1 box	Hammer.
1m	Insulated wire #18.
5m	Coaxial line (50 ohm).
4 each	BNC connector.
30m	Nylon twine.
6 each	Break up Insulator.
1 each	Water pipe clamp.
1 each	Broadband Balun.
6 each	Alligator Clip.
1 each	6" Crescent wrench.

ELECTROMAGNETIC COMPATIBILIITY ANALYSIS CENTER (ECAC) CAPABILITIES AND SERVICES

BACKGROUND

The effectiveness of the command, control, and communications system, the ability of the system to respond to a rapidly changing tactical situation will determine the degree of success on the modern battlefield. The growing importance of effective communications systems has increased the requirement for accurate and timely communications-electronics engineering analysis support for combat units. The Joint Chiefs of Staff (JCS) has established support to operational units as the highest priority of the Electromagnetic Compatibility Analysis Center (ECAC). Operational support is defined as the "Communications-Electronics (C-E) engineering analysis provided by ECAC to the Joint Chiefs of Staff, Unified/Specified Commands, and operational commanders to assist in the execution of their mission." Operational support to the Marine Corps consists of providing C-E engineering analysis support to Marine Corps units to ensure the efficient use of C-E equipment resources and to attain compatibility with the environment.

ECAC has been providing operational support to the Marine Corps since 1973. Much of the analysis support has been on a rapid-response basis to requests by Marine Corps communications personnel during exercise or contingency planning. Some of the exercises the ECAC has supported include: KANGAROO II, June 1976; 3D MAW JAVELIN, Oct 1976; RAVEN BUTTE, Feb 1977; BOLD GUARD and NORTHERN WEDDING, Sep 1978; and MAGEX 80, Korea, 1980. Examples of long term exercises that ECAC has supported are: TEAMWORK 76 and 80, DISPLAY DETERMINATION 77 and 79, and the SOLID SHIELD series. ECAC-CR-77-051, entitled RAPID RESPONSE OPERATIONAL SUPPORT TO THE U.S. MARINE CORPS, and published in August 1977, described the operational support analyses available to the U.S. Marine Corps. Since then these analyses have been upgraded and the responsiveness to Marine Corps operational units has been increased.

OBJECTIVE

The objective of this report is to describe the various analytical capabilities and input data required for Marine Corps communications-electronics engineering and electromagnetic compatibility support.

Note: Appendix II is professional reference material designed to enhance your abilities ONLY; this information is not tested in this course.

OPERATIONAL SUPPORT ANALYSIS CAPABILITIES

The C-E Annex (Annex K), to the Operation Plan/Order is developed by identifying the C-E equipment and personnel resources needed to support the commander's concept of operations. The anticipated physical and electronic environment is then identified and an assessment made as to how the environment will affect the unit's ability to accomplish its mission. ECAC provides operational support by assisting Marine Corps units in identifying the physical and electronic-environment and then providing analysis support assessing the effect of the environment on the unit's ability to accomplish its mission. The following are representative of the types of operational support analyses that are provided to Marine Corps units on a regular basis:

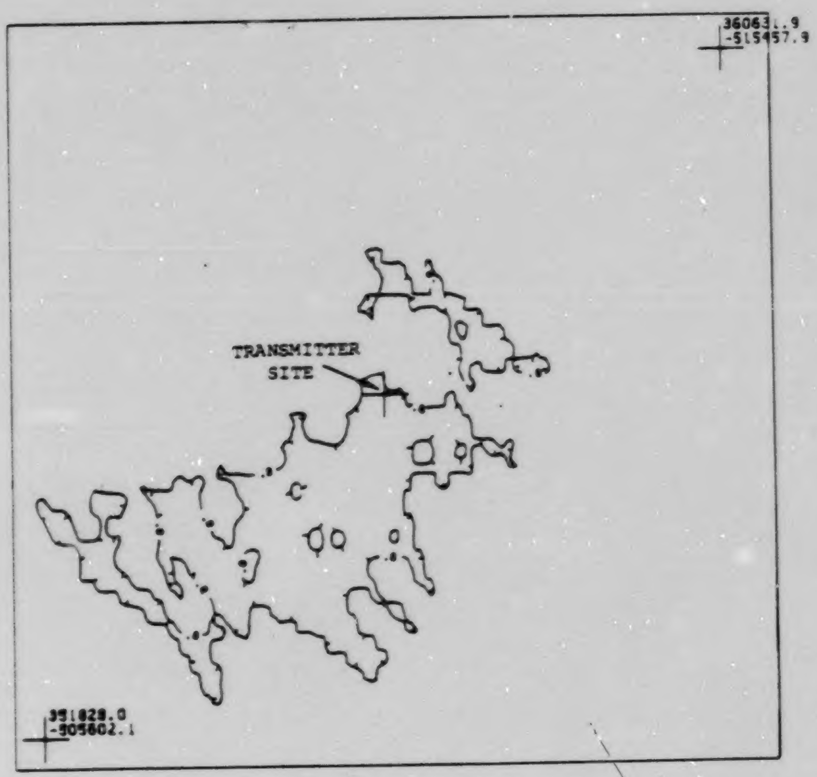
(1) Radio line-of-sight coverage overlays.*
(2) C/E equipment signal coverage overlays.*
(3) HF skywave propagation charts.
(4) HF groundwave propagation predictions.
(5) 4/3 earth terrain profiles.
(6) Point-to-point multichannel circuit reliability.
(7) Limited frequency analysis.

* Indicates that digitized tropagraphic data is required to provide the analysis.

ECAC's data base contains digitized topographic data obtained from the Defense Mapping Agency for the following general areas: CONUS, Hawaii, Southern Alaska, Korea, Northern Canada, Canadian and Mexican border areas, most of Europe, Mediterranean coastal areas and larger islands, Persian Gulf area, the other Middle Eastern Countries, and Southeast Asia. Other data blocks have been requested from the Defense Mapping Agency (DMA) and will be added to the ECAC data base upon completion of the digitizing process by DMA.

LINE-OF-SIGHT (LOS) COVERAGE OVERLAYS

LOS coverage overlays indicate the radio LOS around radio and radar equipment. This analysis is especially useful in choosing antenna location for tactical radios, microwave terminals, and other LOS communications equipment. Figure AII-1 is an example of a contoured radio LOS coverage overlay for a tactical transmitter. Tick marks on the contour lines point to the areas in which there is radio LOS to the transmitter. Radio LOS coverage overlays may also be produced where X's indicate no radio LOS to the transmitter and blanks indicate radio LOS. Figure AII-2 is an example of a highspeed printer (HSP) LOS coverage overlay using X's and blanks to indicate radio LOS. The HSP option for LOS coverage overlays takes less computer time to produce and are especially useful for selecting radio relay points. Therefore, this type of output may be produced depending on the analysis requirements. Overlays are normally provided at a map scale of 1:250,000, but may be varied to meet user requirements. Figure AII-3 is an example of an LOS coverage overlay for a radar equipment. The coverage contours on figure AII-3 provide a plot showing the target acquisition distance versus azimuth for targets at various altitudes. Target altitudes may be specified above mean sea level or above terrain. In this example target altitudes of 5, 10, 15, and 20 thousand feet above mean sea level are specified. Radio coverage overlays are usually provided in 16" x 12" size for a 1:3,000,000 scale map, but other map scales can be provided as required. The coverage contours on figure AII-3 represent points at which a target flying directly toward the site, at the azimuth and altitude indicated, will first be detected. Figure AII-4 is an example of a radar coverage overlay for a target at an altitude of 1000 feet AGL, and illustrates radar coverage when an aircraft or missile is using terrain-following tactics. The following information is required by ECAC to produce LOS coverage overlays:


360631.9
-515457.9
TRANSMITTER
SITE
351828.0
-505602.1

SITE ID	QTY	UNITS	SURFACE ID	MAP RATIO	SCALE
EMBASSY ST	DS	(FT)	1	500000	1.00

Fig AII-1. Contoured radio line-of-sight overlay.

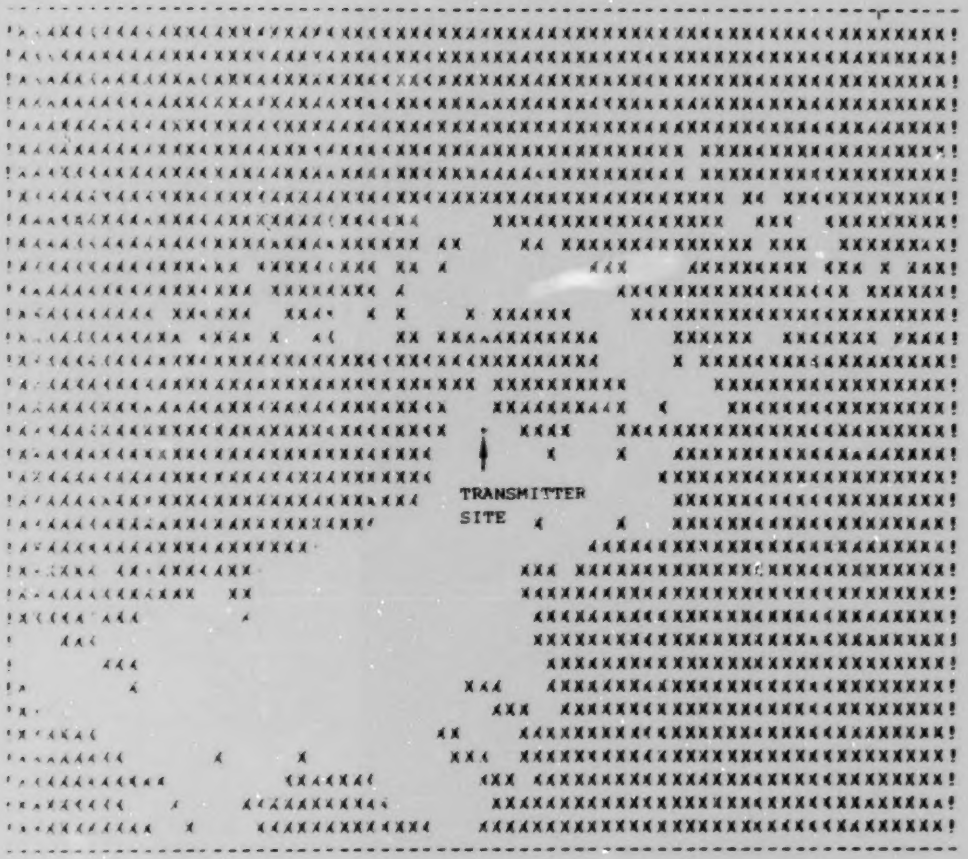

TRANSMITTER
SITE

Fig AII-2. High-speed print radio line-of-sight overlay.

```
TARGET ACQUISITION OVERLAY

TRANSVERSE MERCATOR PROJECTION - SPHERE

SITE IDENTIFICATION:  SAMPLE          SITE LATITUDE:  34 DEG 15 MIN 19 SEC N SITE LONGITUDE:

118 DEG 18 MIN 40 SEC W

MAP RATIO:  3000000: 1  REFRACTIVITY INDEX:  285.  ELEVATIONS EXTRACTED BY 4 POINT METHOD
ELEVATIONS CALCULATED AT 30 SECOND INTERVALS SITE ELEV(FT):2837.00 ANTENNA HEIGHT(FT): 20.0
ALTITUDES ARE ABOVE SEA LEVEL     ?  INDICATES MISSING DATA   X INDICATES SITE LOCATION OTHER
SYMBOLS:               5          10                15              20
TARGET ALTITUDES:   5000.00     10000.00         15000.00       20000.00
```

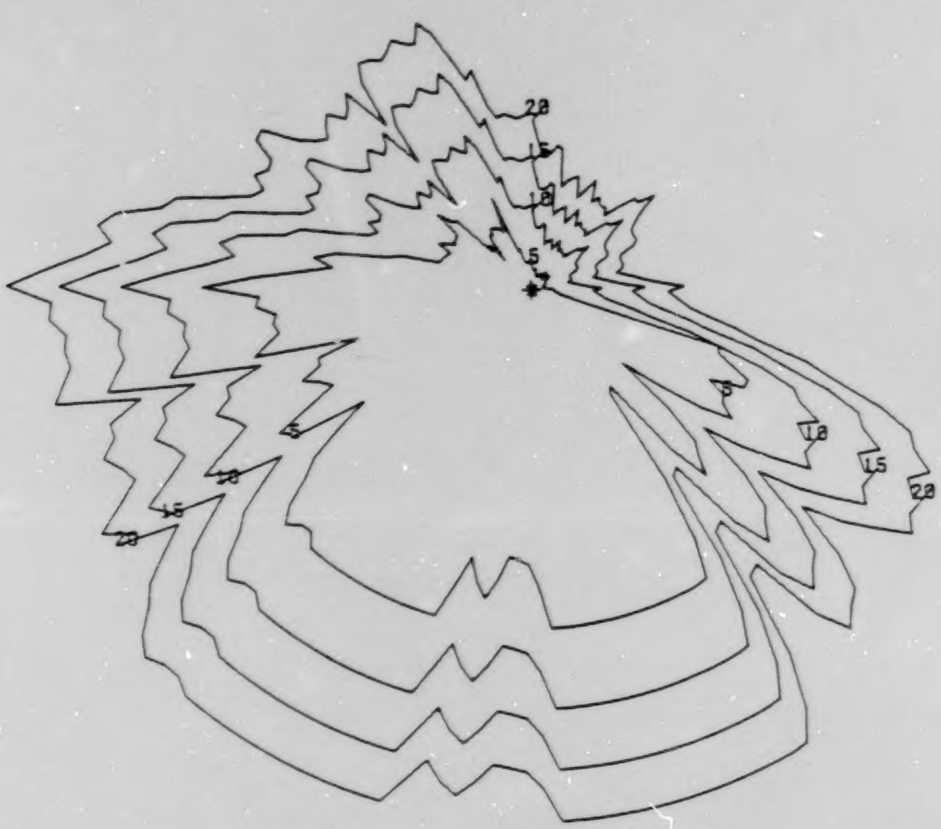
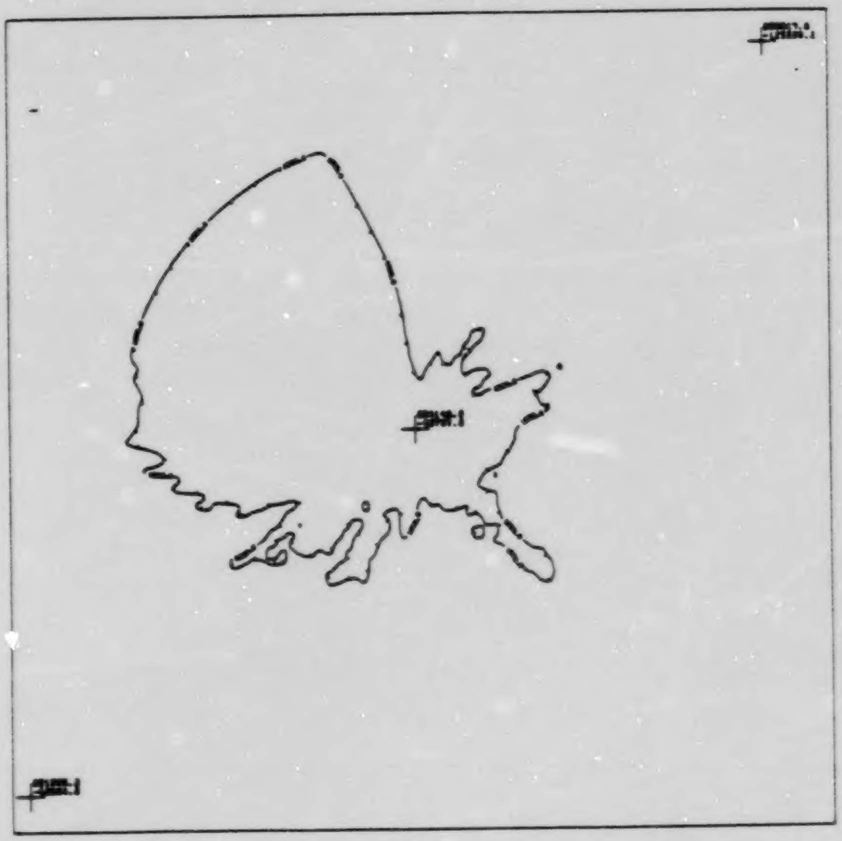


Fig AII-3. Radar LOS coverage overlay at multiple altitudes.



SITE ID	QTY	UNITS	SURFACE ID	MAP RATIO	SCALE	PROJECTION
SAMPLE PLLM	DS	(FT)	3	1000000	1.00	T M SPHERSID

Fig AII-4. Radar LOS coverage for terrain-following tactics.

(1) Map scale (1:3,000,000 map scale will be used for radar equipment coverage unless otherwise specified, 1:250,000 will be used for radio equipment coverage unless otherwise specified).

(2) Site coordinates in UTM (geographic optional).[a,b]

(3) Transmitter antenna height.

(4) Receiver antenna height (for radio equipment) or target altitude above mean sea level or above ground level (for radar LOS coverage).

COMMUNICATIONS-ELECTRONICS (C-E) EQUIPMENT SIGNAL COVERAGE

C-E equipment signal-coverage overlays are used to depict the signal strength around a transmitter taking into account such circuit parameters as transmitter power, antenna gains, receiver sensitivity, and topographic data describing the path. Two typical applications of this capability are: (1) prediction of the area of reliable communications for tactical communications equipment and (2) determination of the susceptibility of friendly C-E equipment to enemy jamming/intercept. Signal-coverage overlays are produced to scale (normally at 1:250,000) and may be used directly with standard military maps. Figure AII-5 is an example of a VHF area signal-coverage overlay. The following information is required:

(1) Equipment nomenclature.

(2) Site coordinates in UTM (geographic optional)

(3) Site elevation.

(4) Antenna heights.

(5) Optional information if known, transmitter power, emission, receiver sensitivity.

(6) Antenna gain.

---

[a] If UTM either grid zone and square (i. e., 11SMG635845), or grid zone and full UTM coordinates (i. e., 463500E 3684500N) must be provided.

[b] UTM - Universal Transverse Mercator.

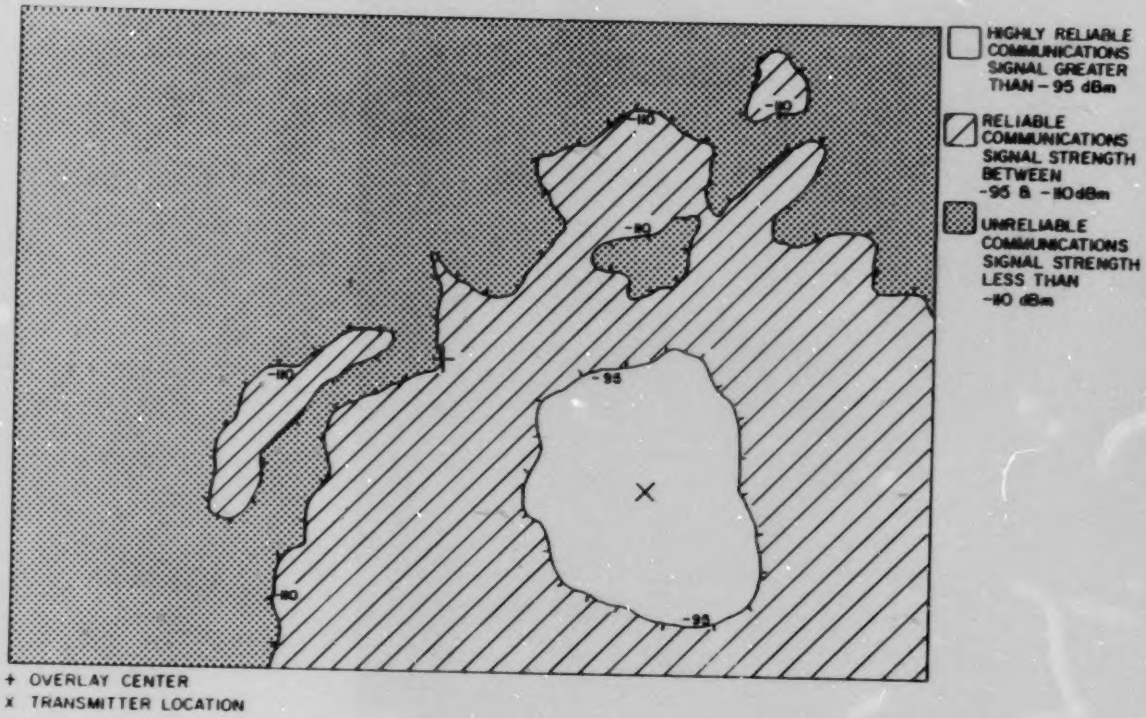

-110
-110
-110
-110
-110
-95
-95
HIGHLY RELIABLE COMMUNICATIONS SIGNAL GREATER THAN -95 dBm
RELIABLE COMMUNICATIONS SIGNAL STRENGTH BETWEEN -95 & -110dBm
UNRELIABLE COMMUNICATIONS SIGNAL STRENGTH LESS THAN -110 dBm
+ OVERLAY CENTER
x TRANSMITTER LOCATION

Fig AII-5. VHF signal-coverage overlay.

HF SKY WAVE PROPAGATION PREDICTION

HF sky wave propagation predictions describe the usable frequencies and the circuit reliability between a transmitter and receiver. Figures AII-6 through 9 illustrate the most common formats for ECAS HF predictions that are available to FMF units (methods A through D). Methods A and D provide the frequency of optimum transmission (FOT), take-off angle (ANG) and reliability (in %) between two points for a 24-hour period. Methods B and C provide predictions for the maximum usable frequency (MUF), FOT and the lowest usable frequency (LUF) for an HF sky wave. The following input data is required by ECAC to produce an HF sky wave prediction.

(1) Day, month, year of start and end of transmission.

(2) Transmitter site name.

(3) Receiver site name.

(4) Transmitter and receiver site coordinates in UTM (geographic optional).[a]

(5) Emission type.

(6) Transmitter power.

(7) Type of earth at each antenna (sea water, desert, marsh, average soil, etc.).

(8) Antenna type (whip, dipole, AS-2259, etc.).

(9) Antenna height and/or length.

(10) Remarks, HF Sky wave Propagation Prediction Desired (method A, B, C, D). Method A will be provided unless otherwise specified.

---

[a] If UTM, either grid zone and square (i. e., 11SMG635845), or grid zone and full UTM coordinates (i. e., 463500E 3684500N) must be provided.

```
                              METHOD A

RESULTS FOR FEB 1, 1981 TO FEB 28, 1981 10 CM FLUX 185.1 SUNSPOT # 142.0
  CHERRY PT NC       TO   BERMUDA             MAG AZS     MILES     KM.
34-35- ON, 77-17- OW 32-22- ON, 64-41- OW 106.38, 300.25  741.6  1193.5
XMTR:  CONSTNT GAIN       .OH      L
RCVR:  CONSTNT GAIN       .OH      L
GRD CONSTS.  XMTR:  COND= .0278 DIEL=15.00  RCVR:  COND= .0278 DIEL=15.00
POWER=  1.00KW  3 MHZ NOISE=-148.608W/HZ  TIME= 90 PERCENT  RSN=47.008*HZ
                                 RELIABILITIES
UT      FOT  2.0  3.0  5.0  7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0      ANG

01      11.7  .90  .91  .93  .95   .96   .75   .16     -     -     -     -      23.0
02      10.0  .88  .89  .92  .94   .87   .24     -     -     -     -     -      24.0
03       8.9  .86  .88  .90  .93   .64   .15   .01     -     -     -     -      24.6
04       8.6  .85  .87  .90  .93   .57   .11     -     -     -     -     -      25.0
05       8.4  .84  .86  .90  .92   .53   .09     -     -     -     -     -      25.1
06       8.2  .83  .86  .90  .92   .44   .06     -     -     -     -     -      25.0
07       7.1  .83  .85  .90  .81   .35   .05     -     -     -     -     -      24.5
08       6.6  .83  .85  .89  .70   .20   .02     -     -     -     -     -      24.9
09       5.9  .85  .87  .88  .54   .08     -     -     -     -     -     -      25.0
10       6.0  .89  .91  .91  .58   .10     -     -     -     -     -     -      24.4
11       9.3  .59  .81  .92  .95   .65   .02     -     -     -     -     -      24.4
12      13.5    -  .12  .86  .92   .94   .91   .51   .05     -     -     -      22.6
13      18.0    -    -  .57  .89   .93   .91   .90   .84   .46     -     -      21.4
14      20.5    -    -  .06  .76   .91   .89   .88   .87   .78   .14     -      21.1
15      21.0    -    -  .01  .75   [illegible]   .91   .91   .90   .83   .14     -      21.7
16      20.4    -    -    -  .71   .93   .91   .90   .90   .79   .06     -      22.3
17      19.7    -    -    -  .70   .93   .90   .90   .89   .74   .01     -      22.8
18      19.2    -    -    -  .75   .95   .92   .92   .91   .59     -     -      23.0
19      18.5    -    -  .03  .80   .95   .93   .93   .89   .62     -     -      22.6
20      18.5    -    -  .51  .86   .96   .94   .94   .89   .62     -     -      22.6
21      18.3    -    -  .70  .92   .94   .93   .92   .87   .57     -     -      22.5
22      17.7  .10  .67  .90  .94   .95   .94   .93   .84   .44     -     -      22.4
23      15.9  .92  .94  .95  .95   .96   .95   .90   .64   .19     -     -      22.1
24      13.9  .91  .93  .94  .95   .96   .94   .71   .20     -     -     -      22.3

CHERRY PT NC    TO BERMUDA                                         FEB  1981
```

Fig AII-6. HF sky wave propagation prediction, method A.

```
                                           METHOD B

             RESULTS FOR FEB 1, 1981 TO FEB 28, 1981         SUNSPOT # 142.0
             FROM CHERRY PT NC          34-35-ON     77-17-OW   LMTT EQUALS GMT-5
             TO  BERMUDA                32-22-ON     64-41-OW   LMTT EQUALS GMT-4
             AZIMUTHS:   98.38, 285.35        MAG AZIMUTHS:  106.38, 300.25
             XMTR:  FREQ  2.0-30.0 CONSTNT GAIN      .0 DB
             PCVR:  FREQ  2.0-30.0 CONSTNT GAIN      .0 DB
             PATH LENGTH:   741.6  MILES  1193.5  KM    POWER:    1.00KW
             3 MHZ NOISE:  --148.6 DBW/HZ  RSN:  47.0 OB*HZ   TIME:  90 PERCENT
                   ***HOURS IN GMT ***            ***FREQUENCIES IN MHZ ***

                             DATA IS FOR THE MOST RELIABLE MODE.

                              MUF(MMMM) - FOT (FFFF) - LUF(LLLL)

        00  02  04  06  08  10  12  14  16  18  20  22  00
         +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    30-                                                    -30
      -                                                    -
    28-                                                    -28
      -                                                    -
    26-                                                    -26
      -                                                    -
    24-                                                    -24
      -                              M M M                 -
    22-                                    M               -22  UT  MUF    FOT   LUF
      -                              F F     M M M M       -     1  13.6  11.7    2.0
    20-                           M      F F         M     -20   2  11.7  10.0    3.1
      -                                      F F F     M   -     3  10.7   8.9    4.5
    18-                           F                F F     -18   4  10.4   8.6    4.8
F     -                                                    -     5  10.2   8.4    5.0
R   16-M                                              F   M-16   6   9.8   8.2    4.8
E     -                        M                           -     7   9.4   7.1    5.0
Q   14-                                                    -14   8   8.6   6.6    5.0
U     - F M                   F                          F-     9   7.8   5.9    4.4
E   13-                                                    -13  10   8.0   6.0    2.1
N     -                                                    -    11  10.4   9.3    3.6
C   12-                                                    -12  12  15.2  13.5    6.2
Y     -F M                                                 -    13  20.2  18.00   7.8
    11-                                                    -11  14  23.0  20.5    8.8
I     -       M                                            -    15  23.3  21.0    8.9
N   10-     F   M M                 M -                    -10  16  22.6  20.4    9.2
      -             M                                      -    17  21.8  19.7    9.2
M   09-               M             F        L L L         -09  18  21.3  19.2    9.1
H     -       F F       M                L L       L       -    19  21.1  18.5    8.7
Z   08-           F F      M                               -08  20  21.0  18.5    7.8
      -                  M            L              L     -    21  20.8  18.3    6.5
    07-               F                                    -07  22  20.1  17.7    4.8
      -                 F                               L  -    23  18.5  16.9    2.0
    06-                    F    L                          -06  24  16.2  13.9    2.0
      -                  F                        L        -
    05-          L   L L                                   -05
      -      L L   L                                L      -
    04-                  L                                 -04
      -                     L                              -
    03-   L                                                -03
      -                                                    -
    02- L L                L                          L L -02
        +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       00  02  04  06  08  10  12  14  16  18  20  22  00

                                       UNIVERSAL TIME
```

Fig AII-7. HF sky wave propagation prediction, method B.

```
                          METHOD C


RESULTS FOR FEB 1, 1981 to FEB 28, 1981     SUNSPOT # 142.0
FROM CHERRY PT NC      34-35-0N      77-17-0W      LMTT EQUALS GMT- 5
TO BERMUDA             32-22-0N      64-41-0W      LMTT EQUALS GMT- 4
AZIMUTHS:  98.38, 285.35    MAG AZIMUTHS:   106.38, 300.25
XMTR:  FREQ  2.0-30.0 CONSTNT GAIN   .0 DB
RCVR:  FREQ  2.0-30.0 CONSTNT GAIN   .0 DB
PATH LENGTH:     741.6  MILES    1193.5  KM      POWER:     1.00KW
3 MHZ NOISE:  -148.6 DBW/HZ     RSN:  47.0 DB*HZ      TIME:  90 PERCENT
    *** HOURS IN GMT ***                *** FREQUENCIES IN MHZ ***

                DATA IS FOR THE MOST RELIABLE MODE.

HOUR 0100  0200  0300  0400  0500  0600  0700  0800  0900  1000  1100  1200
MUF  13.6  11.7  10.7  10.4  10.2   9.8   9.4   8.6   7.8   8.0  10.4  15.2
FOT  11.7  10.0   8.9   8.6   8.4   8.2   7.1   6.6   5.9   6.0   9.3  13.5
LUF   2.0   3.1   4.5   4.8   5.0   4.8   5.0   5.0   4.4   2.1   3.6   6.2
REL   .86   .87   .85   .85   .85   .86   .84   .83   .83   .84   .87   .83

HOUR 1300  1400  1500  1600  1700  1800  1900  2000  2100  2200  2300  3400
MUF  20.2  23.0  23.3  22.6  21.8  21.3  21.1  21.0  20.8  20.1  18.5  16.2
FOT  18.0  20.5  21.0  20.4  19.7  19.2  18.5  18.5  18.3  17.7  15.9  13.9
LUF   7.8   8.8   8.9   9.2   9.2   9.1   8.7   7.8   6.5   4.8   2.0   2.0
REL   .80   .75   .78   .77   .80   .82   .83   .83   .81   .83   .84   .86

NOTE:  RELIABILITY FIQURES ARE CALCULATED AT THE FOT
       XXX INDICATES THAT THE LUF IS GREATER THAN THE FOT
```

Fig AII-8 HF skywave propagation prediction, method C.

METHOD D

HF POINT-TO-POINT FEB 1981

BETWEEN CHERRY PT NC AND:

BERMUDA				GUANTANAMO BAY				EL TORO CA				CIGLI TURKEY			
Z	FOT	ANG	REL	Z	FOT	ANG	REL	Z	FOT	ANG	REL	Z	FOT	ANG	REL
1	11.7	23	.87	1	16.0	14	.84	1	28.8	4	.64	1	13.2	7	.36
2	10.0	24	.87	2	13.5	15	.85	2	24.8	4	.63	2	12.8	7	.36
3	8.9	24	.86	3	11.9	16	.86	3	20.7	4	.62	3	11.8	7	.38
4	8.6	25	.85	4	10.8	16	.85	4	17.0	4	.68	4	10.4	7	.45
5	8.4	25	.86	5	10.4	16	.85	5	14.4	4	.72	5	11.3	6	.40
6	8.2	25	.86	6	10.0	16	.85	6	13.6	4	.74	6	14.7	6	.28
7	7.1	24	.85	7	9.7	16	.86	7	13.9	4	.74	7	13.9	5	.23
8	6.6	24	.84	8	8.4	16	.83	8	14.5	4	.73	8	13.4	6	.15
9	5.9	24	.83	9	7.7	16	.82	9	13.5	4	.74	9	12.4	5	.06
10	6.0	24	.85	10	7.4	16	.83	10	12.3	4	.78	10	13.3	5	.04
11	9.3	24	.87	11	9.1	15	.86	11	10.8	4	.80	11	17.2	5	.04
12	13.5	22	.83	12	15.9	15	.82	12	11.0	4	.78	12	24.1	5	.12
13	18.0	21	.80	13	22.3	14	.75	13	16.0	4	.66	13	33.1	5	.16
14	20.5	21	.76	14	26.3	14	.76	14	23.4	4	.58	14	[illegible]	5	.18
15	21.0	21	.78	15	26.8	14	.76	15	30.7	4	.59	15	[illegible]	5	.18
16	20.4	22	.78	16	25.9	14	.76	16	34.9	4	.61	16	30.9	5	.19
17	19.7	22	.81	17	24.7	15	.76	17	37.3	4	.61	17	27.4	5	.18
18	19.2	22	.83	18	23.8	15	.75	18	37.2	4	.61	18	23.6	5	.15
19	18.5	22	.83	19	23.3	15	.75	19	36.7	4	.62	19	20.1	5	.14
20	18.5	22	.84	20	22.7	15	.76	20	36.2	4	.62	20	17.8	6	.14
21	18.3	22	.82	21	22.8	15	.77	21	34.8	4	.62	21	16.0	6	.19
22	17.7	22	.83	22	22.5	15	.76	22	34.9	4	.62	22	15.0	7	.25
23	15.9	22	.85	23	21.3	14	.77	23	34.3	4	.63	23	14.5	7	.30
24	13.9	22	.86	24	18.7	14	.82	24	32.2	4	.64	24	13.6	6	.35

CHERRY PT NC

Fig AII-9. HF sky wave propagation prediction, method D.

HF GROUND WAVE PROPAGATION PREDICTION

The HF Ground wave Propagation Prediction provides the range, in kilometers, over which a ground wave signal may be reliably received during a 24-hour period, taking into consideration the path distance, transmitter power, emission, antenna, and the ground constants (permittivity and conductivity) of the vertical axis, distances along the horizontal axis, and a plotted line generally running diagonally across the graph. Combinations of frequency and distance to the left of the plotted line indicate HF ground wave communications for that circuit that should be reliable for any hour during the day. Combinations to the right of the plotted line should result in unreliable communications. Requests for the HF Ground wave Propagation Predictions may require that ECAC have a map (at least 1:250,000 scale or larger) of the area, in which case an additional two weeks of elapsed time will be required to provide the analysis if ECAC must order maps. Calculations used to produce the HF Ground wave Propagation Prediction do not consider the effects of atmospheric ducting, detailed topography, or foliage. ECAC requires the following input data:

(1) Transmitter site name and coordinates in UTM (geographic optional).

(2) Transmitter Nomenclature.

(3) Transmitter Power (watts).

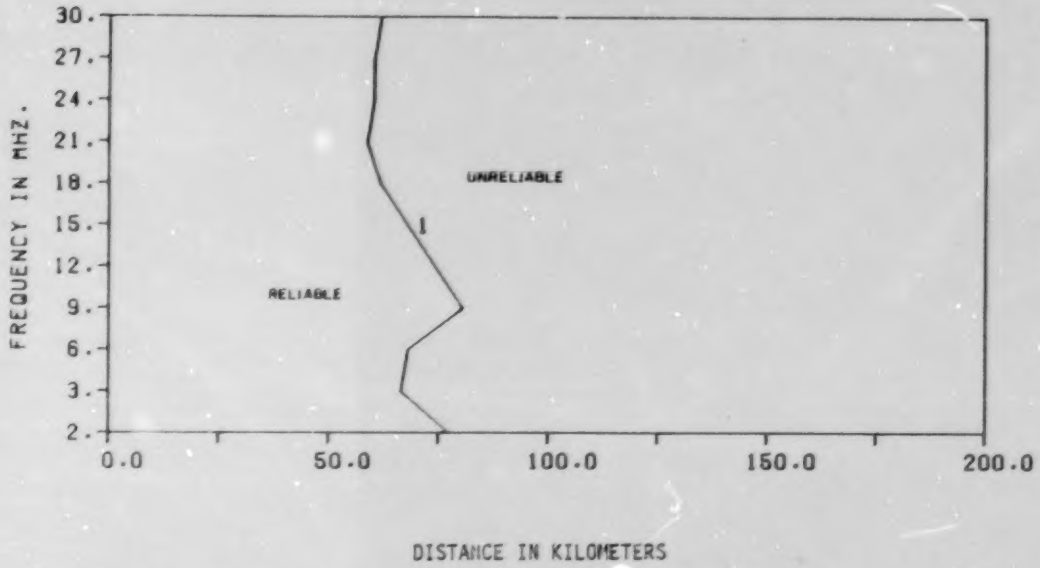
(4) Emission.

(5) Transmitter and Receiver Antenna Heights (feet).

(6) Month and year of use.

---

[a] If UTM, either grid zone and square (i. e., 11SMG635845), or grid zone and full UTM coordinates (i. e., 463500E 3684500N) must be provided.



CIRCUIT PARAMETERS

1. 1000W 3K00J3E 32FT VERTICAL WHIP

NOTE: COMBINATIONS OF FREQUENCY AND DISTANCE TO THE LEFT OF A PARTICULAR LINE SHOULD RESULT IN RELIABLE GROUNDWAVE COMMUNICATIONS: THOSE COMBINATIONS TO THE RIGHT SHOULD BE UNRELIABLE.

Fig AII-10. HF ground wave propagation prediction.

4/3 EARTH TERRAIN PROFILE

Figure AII-11 illustrates a terrain profile along the great-circle path between two points. The terrain profile shows the earth's curvature modified to an effective earth radius of 4/3 in order to show the refracted radio ray as a straight line. Site elevation is indicated along the vertical axis and distance is indicated along the horizontal axis. The dashed line indicates radio line-of-sight along the path. The transmitter and receiver site name, latitude and longitude, and antenna height are indicated at the top of the terrain profile. ECAC requires the following input data:

(1) Transmitter and receiver site name.

(2) Transmitter site coordinates in UTM (geographic Optional).[a]

(3) Transmitter and receiver site elevations above sea level.

(4) Transmitter and receiver antenna height.

POINT-TO-POINT MULTICHANNEL CIRCUIT RELIABILITY

This analysis provides FMF units with an estimate of the reliability of multichannel systems prior to deployment. System reliability is predicted by determining the terrain-dependent path loss, received signal power, and estimated fade margin. The analysis also determines whether the mode of propagation is line-of-sight, troposcatter, knife edge, or combination of modes. Figure AII-12 is an example of a reliability prediction for a number of AN/TRC-97 paths. Data provided in the prediction include path distance, great circle azimuth, horizon angles, and the reliability percentage. The following input data is required by ECAC:

(1) Transmitter and receiver site coordinates in UTM (geographic optional).[a]

(2) Transmitter and receiver site elevations above sea level.

(3) Equipment nomenclature.

---

[a] If UTM, either grid zone and square (i. e., 11SMG635845), or grid zone and full UTM coordinates (i. e., 463500E 3684500N) must be provided.

HILL 76 TO HILL 795
TERRAIN PROFILE - 4/3 EARTH

TX LAT, 37-4-27 N TX LON 127-2-29 E RX LAT, 37-56-3 N RX LON 127-24-41 E
TX ELEV - 249.00 FT RX ELEV - 2600.00 FT
TX ANT HGT = 15.00 FT RX ANT HGT - 15.00 FT

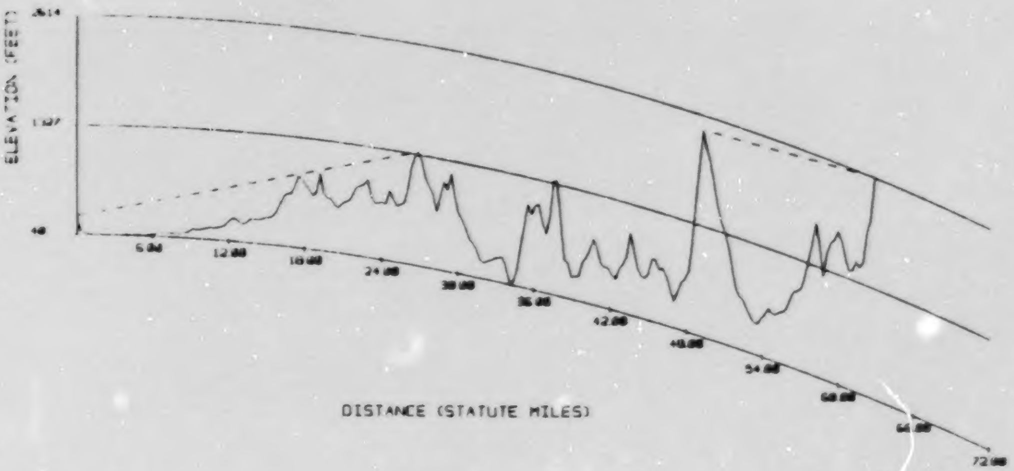


Fig AII-11. 4/3 earth terrain profile.

```
LOS-RE - LINE-OF-SIGHT,' ROUGH EARTH, EMPIRICAL MODEL USED IF THE RAY PATH IS UNOBSTRUCTED AND NEAR THE EARTH"S SURFACE
LOS-FS - LINE-OF-SIGHT,' FREE SPACE (INVERSE SQUARE) LOSS IF THE RAY PATH IS UNDOBSTRUCTED AND WELL ABOVE THE EARTH"S SURFACE
LOS-IR - LINE-OF-SIGHT,' TRANSITION MODE, BASED ON A WEIGHTED COMBINATION OF LOS-FS AND LOS-RE PREDICTIONS
KEB-S  - BEYOND LINE-OF-SIGHT SINGLE KNIFE-EDGE MODEL USING COMMON RADIO HORIZON GEOMETRY
EFFKE  - BEYOND LINE-OF-SIGHT MODEL FOR INTERMEDIATE REGION PROBABLY AT OR JUST BEYOND THE RADIO HORIZON
EFFRED - WEIGHTED COMBINATION OF EFFRE AND RED MOSE WHEN RADIO HORIZONS ARE LESS THAN 2 ST. MI. APART
RED    - ROUGH EARTH DIFFRACTION MODEL
TROSC  - ROUGH EARTH TROPOSPHERIC SCATTER MODEL
EFFOBL - BEYOUND LINE-OF-SIGHT MODEL FOR LONGER PATHS USING DOUBLE KNIFE-EDGE GEOMETERY
DIFSCI - WEIGHTED COMBINATION OF RED AND TROSC MODES WHEN LOSS PREDICTIONS FROM THEM ARE WITHIN 18 DB OF EACH OTHER
DIFSC2 - WEIGHTED COMBINATION OF DIFSCI AND EFFDBL MODES FOR LONGER PATHS WITH TRAVSITIONAL GEOMETRY
DIFSC3 - WEIGHTED COMBINATION OF TROSC AND EFFDBL MODES FOR LONGER PATHS WITH TRANSITIONAL GEOMETRY

NET     SITE NAME    XMTR   P   ****DEGREES*****   PATH  ANT.  ANT.   XMTR  RCVR  PATH   R.S.L.  FADE  ESTIMATE  PROP    DIV.
                     FREQ   O   ANT.  TRUE   MAG.  DIST. GAIN  HGT.   PWR   SENS  LOSS   DBM     MARG  RELIAB    MODE
                     MHZ    L   ELV   BRNG.  BRNG. KILOM DBI   M.           DBM   DB     95%     DB    PERCENT

        SHIELD      4700.0  V  -1.9  238.0  238.0  57.9  38.0  15.0   1KW  -103  200.9  -67.5    35.4  >99.9999 EFFRD   DUAL
        3D MAW      4700.0  V   3.1   57.6   57.6        38.0  15.0

        ANDRSN      4700.0  V  -2.2  203.2  203.2  62.0  38.0  15.0   1W   -103  150.6  -47.3    55.7  >99.9999 LOS-FS  DUAL
        3D MAW      4700.0  V   1.5   23.0   23.0        38.0  15.0

        JEPSON      4700.0  V  -2.6   72.0   72.0  40.5  38.0  15.0   1W   -103  145.6  -42.3    50.7  >99.9999 LOS-FS  DUAL
        EAF         4700.0  V   2.2  252.4  252.4        38.0  15.0


       BLK MT      4700.0  V  -1.8    45.8   45.8  44.4  38.0  15.0   1W   -103  155.0  -51.7    51.3  >99.9999 KEBLS   DUAL
       EAF         4700.0  V   1.4   226.1  226.1        38.0  15.0
```

Fig AII-12. Multichannel circuit reliability prediction.

(4) Transmitter and receiver antenna height.
(5) Transmitter and receiver horizon angles, if critical (if not critical ECAC's computer will calculate horizon angles from the path profile).

FREQUENCY ANALYSIS

This analysis capability provides the requesting unit a list of frequencies compiled from a user-supplied resource list that will not cause or be susceptible to harmonic or intermodulation interference among themselves. Table AII-1 is an example of such a frequency list. Intermodulation of two-signal and three-signal products are tested for, as are harmonically interfering frequencies. The remaining frequencies from the resource list are listed separately from the intermodulation- and harmonic-free frequencies in the order of preference of use, if necessary. Data required by ECAC is as follows:

Table AII-1. Prioritized Frequency List
(all frequencies are in MHz)

Interference-free Frequencies*
30K0F3E Frequencies (10)

31.20	34.33	38.95	44.50	61.45
32.80	36.00	40.55	54.60	62.60

ORDER OF PREFERENCE OF INTERFERING FREQUENCIES

(All frequencies are in MHz)

1. 46.00	4. 34.75	7. 61.80	10. 65.40	13. 41.90
2. 65.35	5. 41.75	8. 34.75	11. 61.80	14. 46.95
3. 39.80	6. 32.15	9. 36.35	12. 60.15	15. 65.75

* All of the interference-free frequencies are free of harmonic and two- and three-signal intermodulation. Of the interfering frequencies, those at the beginning of the list (e. g., 46.00, 65.35, etc.) should be used first.

(1) Frequency resource listing indicating the planned emission.

(2) Radio guard chart (if required).

ADDITIONAL OPERATIONAL SUPPORT SERVICES AVAILABLE FROM ECAC

Varying degrees of operational support are available from ECAC, ranging from the representative operational support requests discussed above to complete and total exercise or contingency communications engineering for areas throughout the world. Analysis capability is not limited to the previously described output, but may also consist of:

(1) More comprehensive propagation analysis (e.g., S/N and signal-level contours, sky wave or ground wave comparisons, etc.).

(2) Complete listing of all frequencies currently in use for any area of interest.

(3) Antenna radiation patterns from most commonly used types of antennas.

(4) Frequency assignment recommendations (based on propagation and EMC considerations).

(5) Determination of antenna locations for best coverage of beaches, objective areas, or avenues of approach, or for best shielding from unwanted intercept.

(6) The most reliable means of communicating between two points.

(7) Topographic data not currently in the data base, but which may be added with sufficient advance notice.

PRACTICAL EXAMPLES OF ECAC OPERATIONAL SUPPORT

DETERMINING THE RADAR COVERAGE AROUND A TACTICAL AIRBASE

Situation

A Marine Air-Ground Task Force (MAGTF) is participating in a NATO exercise which will call for the phasing ashore of the air assests and associated air control functions. The air defense as well as control of the airspace must be planned. The requirements are to determine the radar coverage around the airbase for targets using terrain-following techniques and determine the radar coverage for air control of friendly aircraft.

Approach

The Air Officer identifies possible radar locations for both search and fire control radars. Target altitudes for friendly aircraft of 5, 10, 15, and 20 thousand ft above mean sea level (MSL) and enemy aircraft of 1000 ft above ground level (AGL) are identified. ECAC is requested to provide overlays that will show radar coverage at the specified altitudes for air control purposes and also provide radar coverage overlays for enemy aircraft using terrain-following techniques at various altitudes. The overlays for each radar site are produced to a scale corresponding to maps held by the MAGTF.

Required Information

(1) Equipment nomenclature.

(2) Map scale.

(3) Radar site coordinates in UTM (geographic optional).

(4) Transmitter antenna heights.

(5) Target altitudes (Friendly-MSL, Enemy-AGL).

Output

Radar LOS coverage overlays are produced to show the radar coverage (for targets either MSL or AGL) from each proposed radar site. Figures AII-3 and AII-4 illustrate the types of coverage overlays that would be produced. Using these overlays the Air Officer can determine the adequacy of the radar coverage from the proposed sites for friendly air control and for defense against enemy aircraft. The Air Officer can then recommend radar sites based on his analysis or consider additional sites for analysis, if necessary.

DETERMINING THE OPTIMUM GROUND SURVEILLANCE RADAR DEPLOYMENT LOCATION

Situation

The Commanding Officer of the 2nd Battalion 6th Marines plans to deploy the battalion ground-surveillance radar during an upcoming exercise. The battalion commander wants to employ the ground surveillance radars to aid in detection of enemy forces and has instructed the S-3 to determine the optimum location for deployment of the equipment.

Approach

By conducting a map study, tentative positions for deploying the radar are identified. ECAC is requested to provide 2/6 with radar LOS coverage overlays at a scale of 1:250,000 for these locations. The radio LOS coverage overlays will indicate the LOS coverage from each location and, conversely, show gaps in the radar coverage.

---

[a] If UTM, either grid zone and square (i. e., 11SMG635845), or grid zone and full UTM coordinates (i.e., 463500E 3684500N) must be provided.

Required Information

(1) Site coordinates in UTM (geographic optional).

(2) Site elevation.

(3) Antenna height.

(4) Equipment nomenclature.

Output

LOS coverage overlays for each proposed site are produced (figure AII-13). For this radar site avenues of approach Red and Green are not under surveillance by the radar, while avenue of approach Blue is well covered. Based on the coverage from each of the proposed radar sites, the communications officer can recommend an optimum location to site the equipment.

DETERMINING THE LOCATION OF A VHF FM TACTICAL RADIO RELAY SITE

Situation

The Communications-Electronics Officer of the 4th MAB must ensure that VHF FM communications are available between the 4th MAB headquarters and the 6th Marines CP locations for an upcoming exercise. The exercise play will extend the communication ranges for the VHF FM tactical radios so that LOS communications between the two CP's will not be possible. A radio relay site needs to be selected to ensure that LOS tactical communications are maintained.

Approach

Tentative CP locations for the 4th MAB and 6th Marines are identified. VHF radio LOS coverage overlays are requested for the proposed relay sites.

---

[a] If UTM, either grid zone and square (i. e., 11SMG635845), or grid zone and full UTM coordinates (i. e., 463500E 3684500N) must be provided.

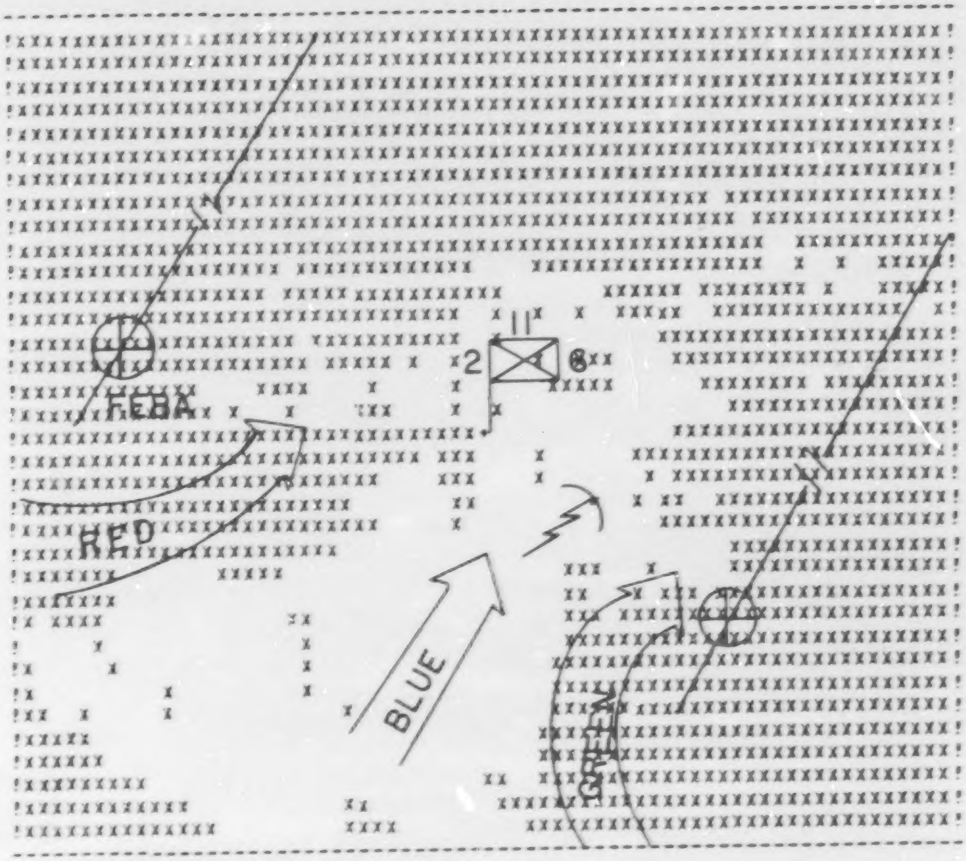

FEBA
RED
11
2
8
BLUE
GREEN

Fig AII-22. Ground surveillance radar coverage.

The LOS coverage overlays will indicate the radio LOS from each of the proposed relay sites and will aid in selecting the site that provides radio LOS to both CP locations.

Required Information

(1) Equipment nomenclature.

(2) Map scale of the overlay.

(3) Site coordinates in UTM (geographic optional).[a]

(4) Transmitter antenna height.

(5) Receiver antenna height.

Output

Radio LOS coverage overlays are produced at the scale requested (normally 1:250,000). Figures AII-14 and AII-15 illustrate the overlays produced to solve the problem of finding a suitable radio relay site. The LOS coverage overlays show that relay site A is not acceptable because there is no radio LOS to both CP's while site B provides radio LOS to both CP locations. Therefore, relay site B is selected as a relay for the exercise.

DETERMINING THE AREA AROUND A TRANSMITTER IN WHICH RELIABLE COMMUNICATIONS ARE POSSIBLE

Situation

The communications officer of the 8th Marines is planning the communications support for an upcoming exercise. Based on a preliminary analysis of the operation plan, he has concluded that the personnel equipment resources of the communications platoon are inadequate to support the scheme of maneuver. Specifically, the plan will require that a number of VHF FM radio relay sites be established in order to provide reliable communications from the regimental CP to the maneuver battalions. If some of these relay sites could be eliminated, the communications platoon could support the exercise. Otherwise, the commanding officer must be advised that additional equipment and personnel are required.

Approach

Locations for the regimental CP are determined. Based on these locations and the possible location of other CP's, the area in which tactical communications will be required is defined. Using the parameters for the equipments and antennas, estimates of the transmitter power levels around the regimental CP location can be made taking into account signal power losses from both terrain and vegetation. In this case a previous recon of the area has shown that vegetation will not be significant in attenuating the transmitter signal. ECAC is requested to provide signal-coverage overlays from each regimental CP location using parameters representing the C-E equipment and antennas that will be deployed. The signal-coverage overlays can be produced to indicate reliable areas of communication around the regimental CP. Proposed maneuver battalion locations will then be plotted on the overlay and a determination made as to whether reliable communications are possible between the regiment and battalion CP's. If reliable communications are possible, a recommendation could be made to eliminate some of the planned VHF radio relay sites.

Required Information

(1) Equipment Nomenclature.

(2) Site coordinates in UTM (geographic optional).[a]

(3) Site elevation.

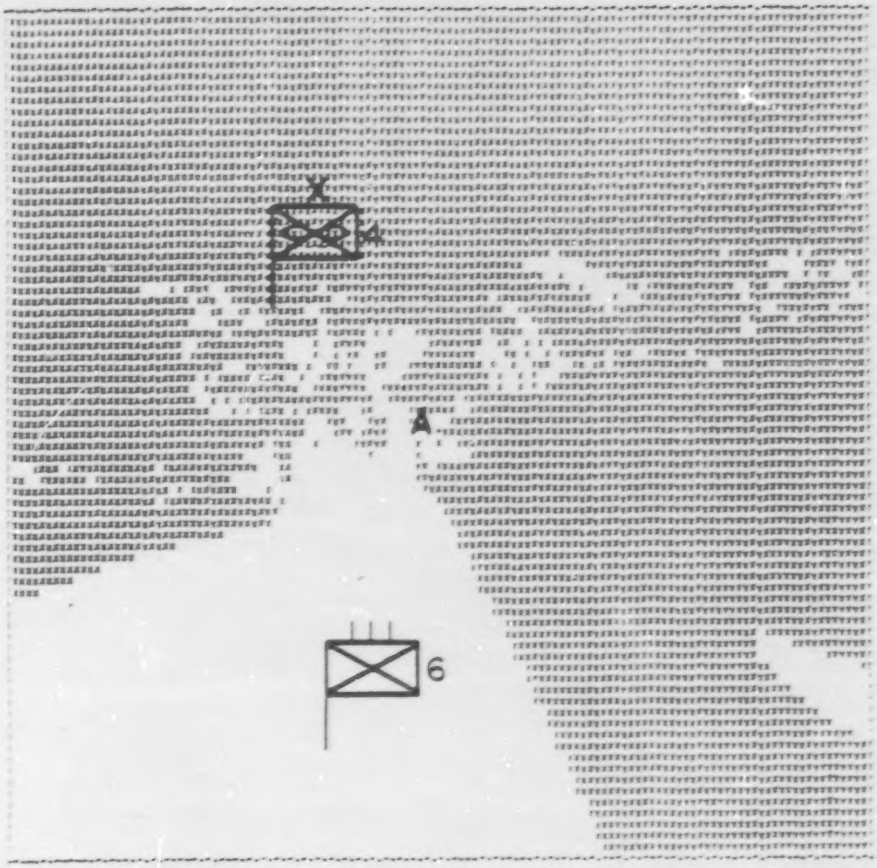
(4) Antenna heights.

(5) Transmitter power, emission and receiver sensitivity.

(6) Antenna gain.

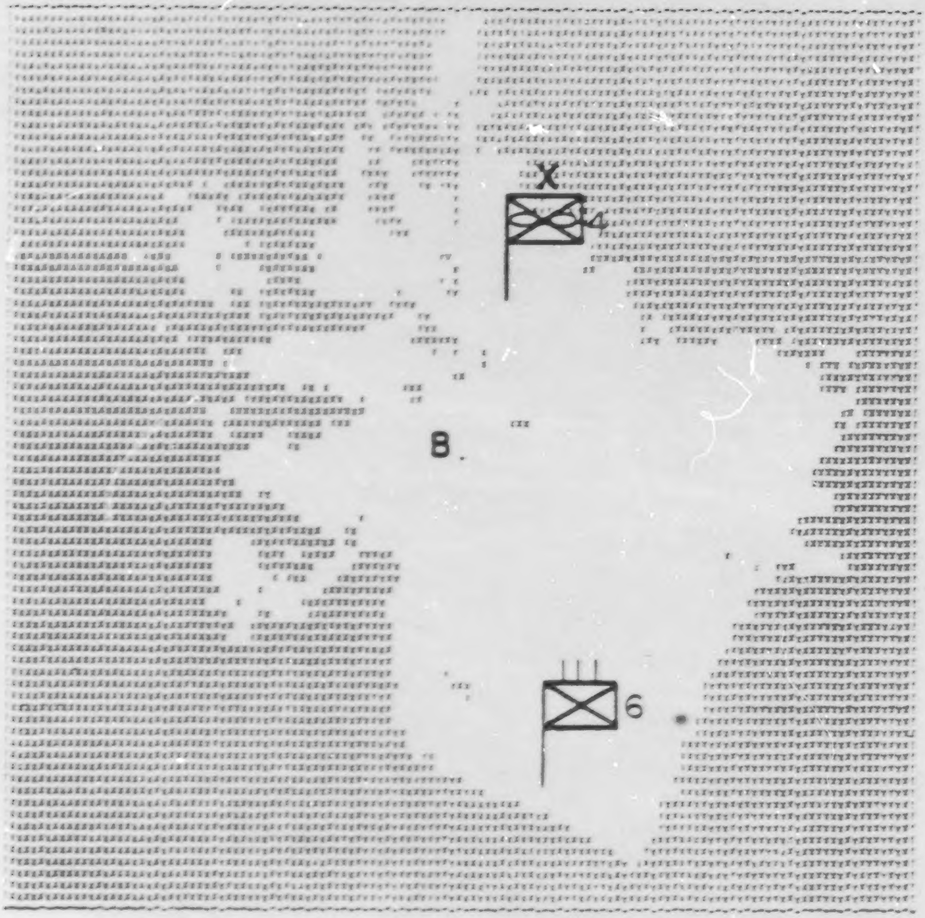
---

[a] If UTM, either grid zone and square (i. e., 11SMG635845), or grid zone and full UTM coordinates (i. e., 463500E 3684500N) must be provided.



GRID SHOWING DEGREE OF SHIELDING

Fig AII-14. VHF radio relay site selection, site A.



GRID SHOWING DEGREE OF SHIELDING

Fig AII-15. VHf radio relay site seleccion, site B.

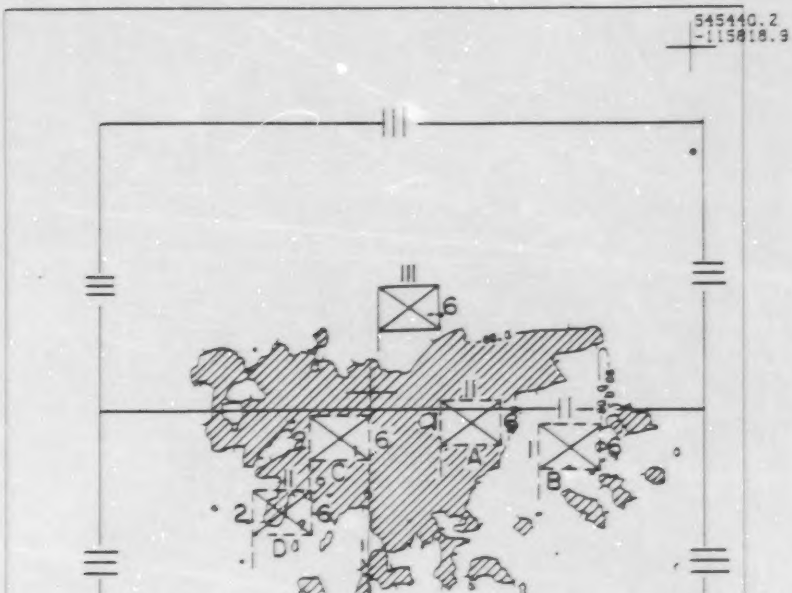
Output

Received Signal Level (RSL) contour overlays are produced for each proposed regimental CP location (figure AII-16). The overlay shows the regimental CP locations and planned maneuver battalion locations. The hashed area indicates where reliable communications from the regiment can be expected. For instance, if battalion CP's were established at Sites A and C, reliable communications with the regimental CP would be expected. Sites B and D are in an area of predicted unreliable communications. If planned battalion CP and relay locations are in areas of reliable communications, then the requirement for a radio relay would be eliminated. These overlays allow the user to assess areas of reliable communications against planned radio relay and battalion CP sites and then make a determination as to whether some planned relays could be eliminated, thus freeing up equipment and personnel resources to support the exercise.

DETERMINING THE SUSCEPTIBILITY OF C-E TRANSMITTERS TO ENEMY RADIO DIRECTION FINDING

Situation

The unit is scheduled to participate in an exercise in which Electronic Warfare (EW) play will be stressed. The communications officer is responsible for ensuring that deployed C-E equipment takes into account the ability of the enemy to conduct direction finding (DF) operations against the unit C-E transmitters. He is especially concerned about the VHF FM radio employed on the tactical circuits. The S-3 has asked that recommendations be made for CP locations that will minimize the enemy's capability of conducting successful direction finding operations against the VHF FM C-E equipment.


545440.2
-115818.9
532755.4
-33025.1
A
B
C
D
6
2

SITE ID	QTY	UNITS	SURFACE ID	MAP RATIO
SAMPLE PLLM	RS	DBM	2	1000000

Fig AII-16. Predicting reliable VHF radio communications.

Approach

Each proposed friendly CP location is identified. The S-2 is contacted for information concerning possible enemy DF unit locations. Based on this location data and equipment characteristics of the friendly C-E equipment and the enemy DF equipment, signal-coverage overlays can be produced which will indicate areas in which friendly transmitters are susceptible to enemy DF operations. ECAC is contacted and requested to produce signal-coverage overlays which will indicate the susceptibility of each proposed battalion CP location. The overlays are requested at a scale of 1:250,000 so that they can be used with maps held by the unit. Ideally, CP locations can be found that will allow for tactical communications between friendly units yet hinder the enemy, through terrain masking, from successfully employing his DF capability.

Required Information

(1) Equipment Nomenclature (friendly and enemy).

(2) Site coordinates, enemy and friendly, in UTM (geographic optional).[a]

(3) Site elevations (friendly and enemy).

(4) Antenna heights (friendly and enemy).

(5) Friendly transmitter power, emission and enemy receiver sensitivity.

(6) Friendly and enemy antenna gains.

Output

Signal-coverage overlays are produced at a scale of 1:250,000 for each of the likely enemy DF locations (figure AII-17). Each overlay illustrates the ability of the suspected DF units to intercept the VHF FM transmitter signals from the proposed battalion CP's. Using these overlays, recommendations for CP locations are made to the S-3 which can limit the effectiveness of the enemy's DF capability. In this case proposed battalion CP site B would not be used because of the likelihood of successful DF operations against friendly C-E equipment at that location.

PREDICTING THE PROBABILITY OF ENEMY JAMMER SUCCESS IN JAMMING REGIMENT-TO-BATTALION COMMAND AND CONTROL AND CONTROL CIRCUITS

Situation

The Regimental Communications Officer is planning for an exercise in Europe. The Commanding Officer is concerned that aggressor forces will jam his command and control circuits to the two maneuver battalions playing in the exercise. The regimental CO requests recommendations for CP locations that will minimize the enemy's ability to jam the regimental command and control circuits.

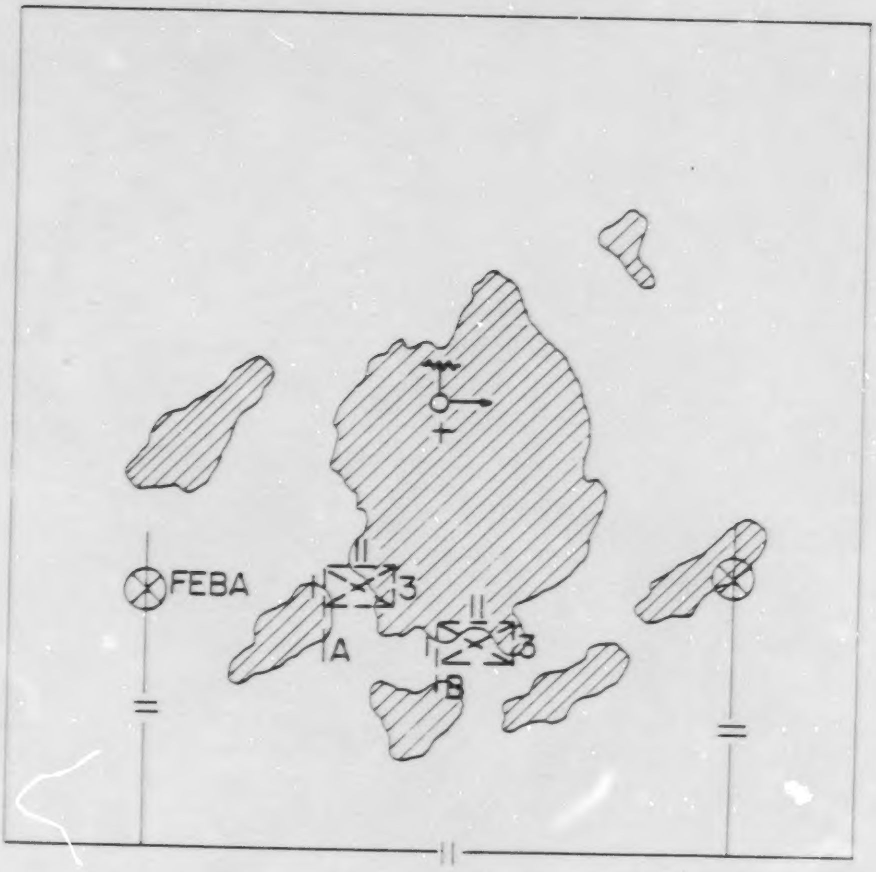
Approach

Receivers at the battalion CP locations will be more susceptible to jamming than will receivers at the regimental CP location because of their proximity to the enemy. Therefore, selection of battalion CP locations will be critical in limiting the effectiveness of the enemy's jamming capability. Assuming that a reliable circuit is possible between the battalions and the regiment, signal strengths can be predicted from C-E equipment at the regimental CP versus signal strengths from enemy jammers in the operating area and an assessment made of the effectiveness of enemy jamming signal strength will be more powerful than the friendly signal strength. ECAC is requested to provide J/S contour overlays for each proposed regimental CP location.

Tentative regimental CP locations and enemy jammer locations are identified along with technical parameters of friendly VHF FM radios and the enemy jammers. The J/S contour overlays will be produced to a scale usable with maps held by the regiment. A J/S ratio greater than zero will indicate that the VHF FM radio at that location is susceptible to being jammed.

---

[a] If UTM, either grid zone and square (i. e., 11SMG635845), or gird zone and full UTM coordinates (i. e., 463500E 3684500N) must be provided.



Area susceptible to enemy direction finding.

Fig AII-17. Predicting susceptibility to enemy DF.

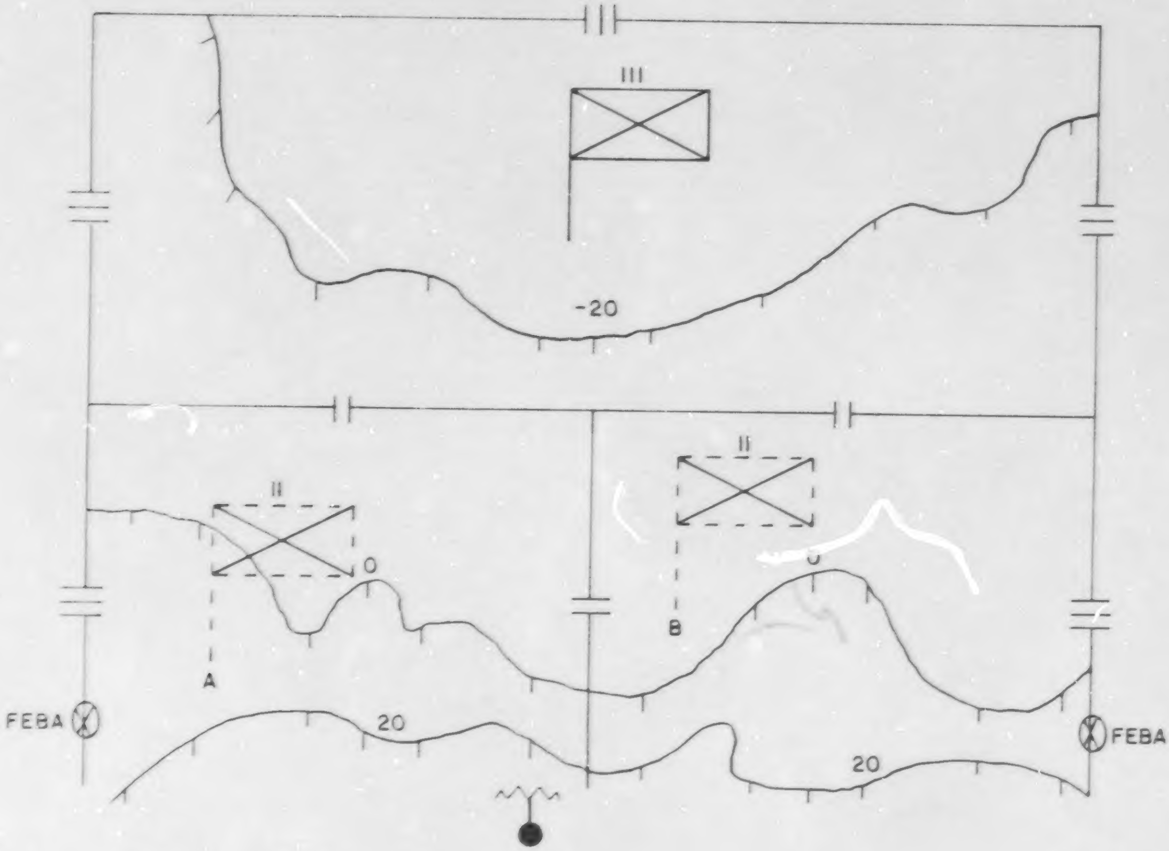

III
-20
II
II
0
0
A
B
FEBA
FEBA
20
20

Fig AII-18. J/S signal coverage overlay.

Required Information

(1) Equipment nomenclature (friendly and enemy).

(2) Site coordinates for Regt. CP and jammer locations in UTM (geographic optional). [a]

(3) Site elevation (friendly and enemy).

(4) Antenna heights (friendly and enemy).

(5) If known, transmitter power and emission (friendly and enemy).

(6) Antenna gain (friendly and enemy).

Output

J/S signal-coverage overlays are produced which show the jammer-to-friendly signal coverage for each of the suspected jammer location (figure AII-18). Figure AII-18 shows the J/S ratio plotted at three levels 20, 0, and -20 dB. Tick marks point to the higher J/S ratio levels. It also shows two proposed battalion CP locations at points A and B. If battalion CP location A were selected these equipments would be susceptible to enemy jamming, since they would be located in an area in which the J/S ratio is greater than zero. The proposed battalion CP locations at point B would be acceptable for planning purposes since the friendly radio signals would be greater than the jammer signal resulting in a J/S ratio of less than zero. J/S signal coverage-overlays are produced for each different regimental CP and jammer location. Using these overlays, recommendations for battalion CP locations that will reduce the effectiveness of the enemy's jamming capability are made.

DETERMINING THE OPTIMUM HF FREQUENCIES TO USE IN A PLANNED HF SKY WAVE CIRCUIT

Situation

The 1st Marine Brigade has a requirement to establish an HF circuit between MCAS Kaneohe and MCAS El Toro. The Brigade CEO instructs his frequency manager to determine what frequencies should be used on the circuit. The CEO also wants a recommendation whether the 32-foot whip antenna could be used on the circuit.

Approach

The frequency manager identifies the combinations of transmitter power, antenna, and emission that will be used on the circuit. An AUTODIN message is prepared and sent to ECAC requesting an HF propagations for the path (figure AII-19).

Required Information

(1) Day, month, year of start and end of transmission.

(2) Transmitter site name.

(3) Receiver site name.

(4) Transmitter and receiver site coordinates in UTM (geographic optional). [a]

(5) Emission type.

(6) Transmitter power in watts.

(7) Type of earth at each antenna.

(8) Antenna height and/or length.

---

[a] If UTM, either grid zone and square (i. e., 11SMG635845), or grid zone and full UTM coordinates UTM coordinates (i. e., 463500E 3684500N) must be provided.

R241802ZNOV80

FM CG FIRST MAR BDE

TO RUEBAFA/ECAC ANNAPOLIS MD//CM//

INFO RUHQHQA/CG FMFPAC

RUHQKBA/FIRST RADBN

RUWJGFB/CG THIRD MAW

BT

UNCLAS

SUBJ: HF PROPAGATION PREDICTION REQUEST

1. 5-31 DEC 80

2. MCAS KANEOHE

3. MCAS EL TORO

4. 212712N 1574515W, 334029N 1174210W

5. 3K00J3E

6. 1KW

7. AVG SOIL

8. 32' WHIP

Fig AII-19. HF skywave propagation request.

Output

An HF propagation prediction is provided by AUTODIN for the requested path (figure A II-20). Based on this prediction, the frequency manager decides whether the 32-foot whip antenna can be used on the circuit.

RCTUDJGZ RUEBAFA5362 3391702 0084-0000--RUHOKBA BUHQHQA RUHUGFB.
ZNR UUUUU
R C41702Z DEC 80
FM ECAC ANNAPOLIS MO//CM//
TO RUHQKBA/CG FIRST MAR BDE
INFO RUHCHOA/CG FMFPAC
RUHOKBA/FIRST RADEN
RUHOKBA/COMMSPTCO SEVENTH COMMBN
RUWJGFB/CG THIRD MAW
BT
UNCLAS
SUBJ: REQUEST FOR HF GROUNDWAVE PREDICTIONS (U)
A. FONECON FIRST MAP BDE CEO/ECAC(SSGT ANTON/MR SKINNER) 19 NOV 80

ECAC HF IONOSPHERIC PROPAGATION PREDICTIONS
METHOD 'A'

THE ACCOMPANYING PREDICTIONS DESCRIBE THE OPTIMUM TRAFFIC FREQUENCY (FOT), THE RECOMMENDED RADIATION TAKE-OFF ANGLE (ANG) AND THE PREDICTED RELIABILITY (REL) FOR THE INDICATED CIRCUIT FOR EACH HOUR OF THE DAY AS A FUNCTION OF FREQUENCY, AVERAGED OVER A 30 DAY PERIOD.

MOST HF SKY WAVE CIRCUITS REQUIRE AT LEAST TWO FREQUENCIES - A HIGH 'DAY' AND A LOW 'NIGHT' FREQUENCY. IF THE RATIO OF DAY TO NIGHT FREQUENCIES IS 2 TO 1 OR GREATER, A 'TRANSITION' FREQUENCY WILL USUALLY BE REQUIRED BETWEEN THE TWO TO MAINTAIN THE CIRCUIT DURING SUNRISE AND SUNSET.

THE FOT IS THAT FREQUENCY WHICH WILL REFLECT FROM THE IONOSPHERE 90 PERCENT OF THE TIME. DAY AND NIGHT FREQUENCIES SHOULD BE CHOSEN THAT ARE SLIGHTLY BELOW THE DAY AND NIGHT FOTS. AS CAN BE SEEN IN THE ACCOMPANYING PREDICTIONS, FREQUENCIES LOWER THAN THE FOT MAY HAVE AN OBVIOUSLY HIGHER RELIABILITY. THIS IS BECAUSE THE REL IS BASED ON THE PROBABILITY OF ATTAINING A REQUIRED SIGNAL-TO-NOISE-RATIO (RSN) AND IS THEREFORE A MORE ACCURATE MEANS OF DESCRIBING OPTIMUM FREQUENCIES.

IF HIGH ACCURACY IS DESIRED, IT IS SUGGESTED THAT THESE 30-DAY PREDICTIONS BE AUGMENTED BY THE 24-HOUR PROPAGATION CONDITION FORECASTS ISSUED BY THE USAF GLOBAL WEATHER CENTER OVER AUTODIN WHICH ARE BASED ON CURRENT WORLD-WIDE IONOSPHERIC SOUNDINGS.

RECOMMENDATIONS FOR CHANGES TO THESE PREDICTIONS OR QUESTIONS CONCERNING THEIR INTEPRETATION SHOULD BE DIRECTED TO ECAC'S OPERATIONAL SUPPORT GROUP (SAGO), AUTOVON: 281-02452. THOSE RELATING TO PROJECT COORDINATION OR POLICY MATTERS SHOULD BE DIRECTED TO THE DEPUTY DIRECTOR FOR MARINE CORPS (CM), AUTOVON: 281-2555.

Fig AII-20. HF progagation prediction message.

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PAGE 02  PUEBAFA5362 UNCLAS
        ECAC HF IONOSPHERIC PROPAGATION PREDICTIONS
                            METHOD A

    FOR DEC 1, 1980 TO DEC 31,1980                  SUNSPOT #143.0
    FROM KANEOHE BAY HI      21-27-12N  157-45-15W
    TO EL TORO CA            33-40-29N  117-42-10W
    AZIMUTHS:   62.1, 261.4    MAG AZIMUTHS:
    XMIR:  V.  MONOPOLE      9.8 METERS L
    RCVR:  V.  MONOPOLE      9.8 METERS L
    PATH LENGTH:  2575.9     MILES     4145.5  KM     POWER:      1000.W
    3 MHZ NOISE:  SUBURBAN             RSN:  48.0 DB*HZ  LUF PERCENT:  90

                                RELIABILITIES

    Z    FOT  2.0 3.0  5.0   7.5  10.0  12.5  15.0  17.5  20.0  25.0  30.0   ANG
    01  31.3    -   -    -     -   .15   .32   .44   .51   .54   .29   .03  14.6
    02  27.5    -   -    -   .08   .43   .50   .56   .51   .58   .12   .03  14.2
    03  23.8    -   -  .01   .38   .64   .63   .50   .57   .42     -     -  14.0
    04  20.3    -   -  .20   .60   .74   .59   .56   .41   .10   .01     -  14.1
    05  17.6    -   -  .28   .64   .74   .58   .43   .08   .03     -     -  14.3
    06  15.3    -   -  .27   .62   .64   .50   .09   .01     -     -     -  14.6
    07  13.7    -   -  .27   .62   .64   .24   .03     -     -     -     -  14.9
    08  12.2    -   -  .26   .54   .54   .15   .03     -     -     -     -  15.0
    09  11.7    -   -  .26   .48   .48   .10   .02     -     -     -     -  15.0
    10  11.9    -   -  .25   .52   .52   .13   .02     -     -     -     -  14.9
    11  12.4    -   -  .25   .56   .58   .20   .03     -     -     -     -  15.0
    12  10.8    -   -  .25   .45   .47   .15   .02     -     -     -     -  15.4
    13   9.4    -   -  .28   .44   .26   .04     -     -     -     -     -  15.8
    14   8.9    -   -  .33   .44   .19   .04     -     -     -     -     -  15.9
    15   9.2    -   -  .19   .41   .24   .03     -     -     -     -     -  15.4
    16  16.1    -   -    -   .39   .55   .48   .12   .01     -     -     -  14.3
    17  25.9    -   -    -   .01   .37   .45   .50   .49   .54   .07   .02  13.2
    18  35.7    -   -    -     -   .08   .25   .37   .48   .54   .31   .18  12.7
    19  38.7    -   -    -     -     -   .13   .26   .40   .50   .27   .19  12.9
    20  38.3    -   -    -     -     -   .08   .20   .35   .47   .26   .18     -
    21  37.0    -   -    -     -     -   .06   .18   .33   .45   .27   .17     -
    22  36.0    -   -    -     -     -   .07   .19   .35   .44   .28   .15     -
    23  35.6    -   -    -     -     -   .12   .25   .39   .45   .30   .14     -
    24  33.9    -   -    -     -   .03   .19   .33   .45   .49   .31   .11  15.0
    BT
    RCTUDJGZ RUEBAFA5362 3391702 0084-UUUU
```

Fig AII-20. HF propagation prediction message--continued.

DETERMINING THE RELIABLE DISTANCE FOR HF GROUND WAVE COMMUNICATIONS

Situation

The 3rd Marines are scheduled to participate in a exercise in Korea, and the requirement exists to establish HF command circuits during the exercise. Since the distances of the HF circuits are expected to be 80 km or less, it is possible that many of the circuit requirements could be satisfied using HF ground wave propagation.

Approach

The regimental communications officer identifies the 3rd Marine HF circuit requirements. Transmitter and receiver locations for each circuit are identified along with the transmitter power, emission, and antenna to be used. ECAC is requested to provide HF ground wave predictions for each path.

Required Information

(1) Transmitter site name and coordinates, in UTM (geographic optional).[a]

(2) Transmitter nomenclature.

(3) Transmitter power.

(4) Emission.

(5) Transmitter and receiver antenna heights.

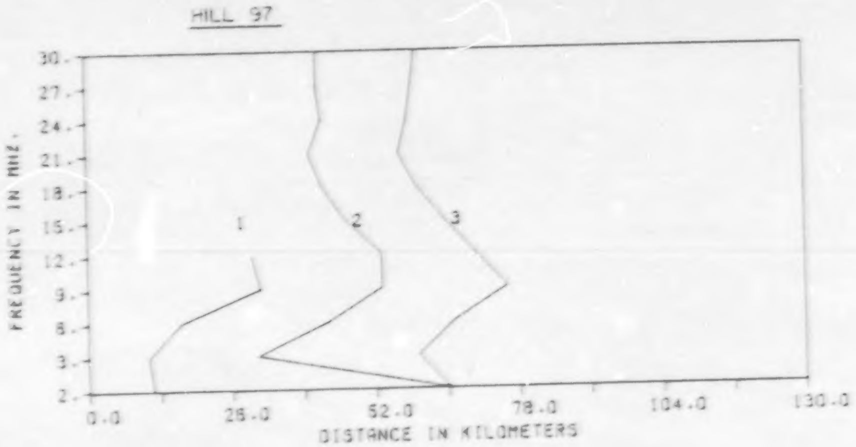
(6) Month and year of use.

Output

HF ground wave propagation prediction charts are produced for each path and power, emission, and antenna combination, predicting the communicability of the path (figure AII-21). Figure AII-21 provides a prediction of the HF ground wave communicability from Hill 97 for three combinations of equipment, emission, and antenna. Using this prediction, an assessment is made whether HF ground wave propagation can be used for this circuit.

---

[a] If UTM, either grid zone and square (i. e., 11SMG635845), or grid zone and full UTM coordinates (i. e., 463500E 3684500N) must be provided.



CIRCUIT PARAMETERS
1. PRC-47 EMISSION 3K00J3E 75W 20FT WHIP
2. MRC-83 EMISSION 3K00J3E 750W 15FT WHIP
3. TSC-15 EMISSION 3K00J3E 750W 32FT WHIP

NOTE: COMBINATIONS OF FREQUENCY AND DISTANCE TO THE LEFT OF A PARTICULAR LINE SHOULD RESULT IN RELIABLE GROUND WAVE COMMUNICATIONS: THOSE COMBINATIONS TO THE RIGHT SHOULD BE UNRELIABLE.

Fig AII-21. Hill 97 ground wave prediction.

ESTIMATING THE COMMUNICABILITY OF VHF FM COMMUNICATIONS PATHS FOR CONTINGENCY PLANNING

Situation

The CCEO of the 1st Marine Division is concerned about the communicability of VHF FM circuits for various contingency plans that the division may be required to support. A rapid assessment of the communicability of each path and determination of which paths will require further analysis is required.

Approach

VHF FM transmitter and receiver locations for each path are identified. The equipment and antennas to be used on each path are identified. ECAC is requested to provide a 4/3 earth terrain profile for each path, indicating the radio LOS along the path. A rapid assessment as to the communicability of the path can be made by identifying whether radio LOS is possible from the transmitter to the receiver. Those paths that do not have radio LOS will be identified for further analysis.

Required Information

(1) Transmitter and receiver site name.

(2) Transmitter and receiver coordinates, in UTM (geographic optional).[a]

(3) Transmitter and receiver site elevations above mean sea level.

(4) Transmitter, and receiver antenna height.

Output

Four-thirds earth terrain profiles are produced for each path similar to the example in figure AII-9. The profiles will indicate whether there is an LOS along the path and will also provide a visual presentation of the profile. From the terrain profiles an estimate of the communicability of each path is made, and those paths requiring further analysis are identified.

---

[a] If UTM, either grid zone and square (i. e., 11SMG635845), or grid zone and full UTM coordinates (i. e., 463500E 3684500N) must be provided.

PREDICTING THE RELIABILITY OF PROPOSED MULTICHANNEL CIRCUITS

Situation

The 1st MAW is planning an exercise in Korea and has identified the requirement for several AN/TRC-97 microwave circuits. Lift requirements for the exercise are being computed, and a determination needs to be made as to whether the AN/TRC-97 assets allocated for the exercise will be sufficient. An estimate of the circuit reliability needs to be obtained in order to determine if additional AN/TRC-97 equipment will be required.

Approach

The proposed transmitter and receiver site locations for each circuit are determined. Since equipment planned for the lift needs to be identified within a matter of days, an AUTODIN message is sent to ECAC requesting a reliability prediction for each circuit. ECAC is requested to provide, by return message, an estimate of the reliability of each circuit.

Required Information

(1) Transmitter and receiver site coordinates in UTM (geographic optional).[a]

(2) Transmitter and receiver site elevations above mean sea level.

(3) Equipment nomenclature.

(4) Transmitter and receiver antenna height.

Output

Each path is analyzed, and an AUTODIN message is sent back to the 1st MAW with an estimate of the reliability of each path (figure AII-22). Additionally, planning parameters for each path are provided to include a recommended power and a recommendation for diversity or non-diversity operation. The path from Hill-76 to Hill-307 has a predicted reliability of less than 50 percent. From this information the CEO directs that a relay site be planned for this link, thus requiring an adjustment in the lift requirements.

DEVELOPING AN INTERFERENCE-FREE MULTICHANNEL FREQUENCY ASSIGNMENT PLAN FROM A RESOURCE LIST

Situation

The division has a training exercise planned for the near future. A list of training frequencies that may be used during the exercise has been obtained from the area frequency coordinator. The frequency assignments may cause interference to VHF FM multichannel assignments.

Approach

The frequency resource list for VHF FM frequency assignments for the exercise is identified along with the VHF FM circuit requirements. Based on this information ECAC is requested to develop an interference-free frequency plan for each site, so that the multichannel assignments could be used simultaneously with single-channel assignments without suffering or causing interference. The frequency resource list will be checked for harmonic as well as two-signal and three-signal intermodulation products, and an interference-free list will be developed.

Required Information

(1) Frequency resource list (including planned emission).

(2) Radio guard chart.

Output

The result of the ECAC analysis is an interference-free frequency resource list similar to the frequency list in table AII-1. ECAC can also be requested to make multichannel frequency assignments. Figure AII-23 is an example of a frequency assignment plan developed for a 1st Marine Division VHF multichannel system.

```
RCTUDJGZ RUEBAFA5266 3451500 0058-UUUU--RUEBANA.
ZNR UUUUU
R 201500Z DEC 80
FM ECAC ANNAPOLIS MD//CM//
TO RUEBANA/ CG FIRST MAW
BT
UNCLAS
                    ECAC MICROWAVE RELIABILITY PREDICTIONS
                                 METHOD E

     THE PREDICTIONS PROVIDE THE NECESSARY INFORMATION FOR SETTING UP MICROWAVE
COMMUNICATIONS CIRCUITS AND ARE PRESENTED IN A FORM SUITABLE FOR INCLUSION IN
COMMUNICATIONS PLANS.  INCLUDED FOR EACH CIRCUIT ARE THE PATH DISTANCE, GREAT CIRCLE
AZIMUTHS, HORIZON ANGLES, RECEIVED SIGNAL LEVEL FOR 95% OF THE TIME, THE CALCULATED
RELIABILITY PERCENTAGE AND THE PROPAGATION MODE.
     THE RELIABILITY IS THE PERCENT OF TIME THE RECEIVED SIGNAL MEETS OR EXCEEDS THE
REQUIRED SIGNAL-TO-NOISE RATIO DURING 95% OF THE TIME.  ALTHOUGH RELIABILITIES LESS
THAN 99% CAN OFTEN BE TOLERATED FOR STRAIGHT VOICE TRANSMISSIONS, A MINIMUM OF 99.99%
IS USUALLY CONSIDERED NECESSARY FOR MULTIPLEXED TRANSMISSIONS.

FOUR PROPAGATION MODE (PM) ABREVIATIONS ARE USED IN THIS METHOD:
     L -LINE OF SIGHT
     D -DIFFRACTION
     C -DIFFRACTION-SCATTER
        (COMBINATION OF DIFFRACTION AND TROPOSCATTER)
     T -TROPOSCATTER
     E -EFFECTIVE DOUBLE KNIFE EDGE
  DIVERSITY CODES (DIV) ARE:  S-SINGLE     Q-QUAD     D-DUAL
     RECOMMENDATIONS FOR CHANGES TO THESE PREDICTIONS OR QUESTIONS
CONCERNING THEIR INTERPRETATION SHOULD BE DIRECTED TO ECAC'S OPERATIONAL
SUPPORT GROUP (SAGO), AUTOVON:  281-2452.  THOSE RELATING TO PROJECT COORDINATION OR
POLICY MATTERS SHOULD BE DIRECTED TO THE DEPUTY DIRECTOR FOR MARINE CORPS (CM),
AUTOVON:  281-2555.


PAGE 02  RUEBAFA5266 UNCLAS
                  ECAC MICROWAVE RELIABILITY PREDICTIONS
                               METHOD E
                                                                                      D
                       P   DEGREES                        ANT        PSL               I
              FREQ     O   ANT   MAG    DIST   XMTR       GAIN       95%   FADE PERCENT  P  V
NET    SITE    MHZ     L   ELY   BRG    KM.    PWR        DBI        DBM   MARG RELIAB.  M  *
***********  *****     *   **** *****   ****   ******     *****      ***** **** *******  *  *
       H-76   4700     V     .5    9.8  113.   1KW        38.0       -11.9 ****<50.0000  T  D
       H-307  4700     V    2.4  189.9                    38.0
       H-76   4700     V     .0   13.6  115.   1KW        38.0       -57.8 45.2>99.9999  D  D
       H620   4700     V    -.4  193.8                    38.0

  BT
  RCTUDJGZ RUEBAFA5266 3451500 0058-UUUU
```

Fig AII-22. Multichannel reliability prediction message.

1st MARDIV MRC-135 ASSIGNMENT

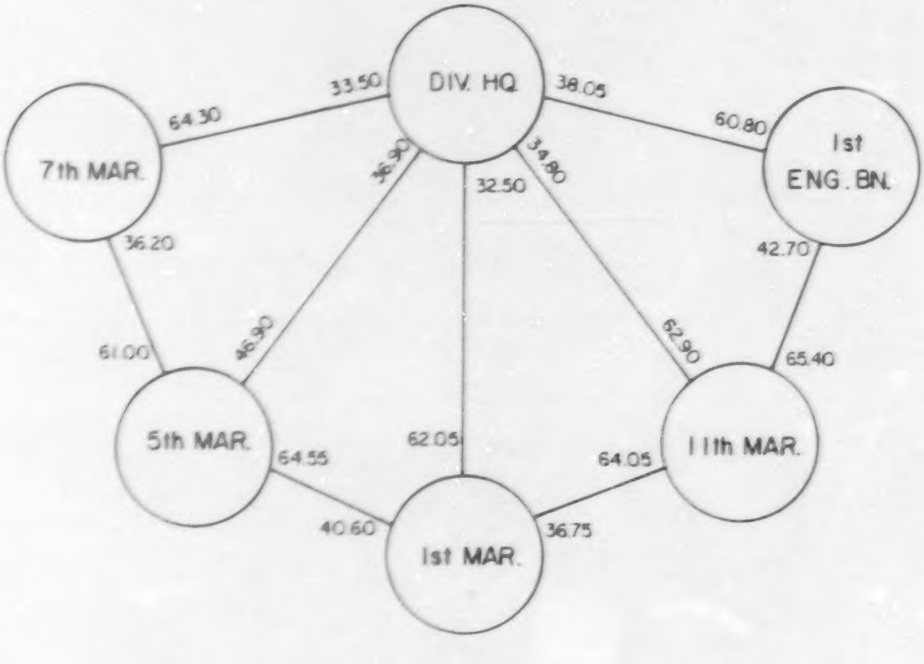

DIV. HQ
33.50
38.05
64.30
60.80
7th MAR.
1st ENG. BN.
36.90
34.80
32.50
36.20
42.70
61.00
46.90
62.90
65.40
5th MAR.
64.55
62.05
64.05
11th MAR.
40.60
36.75
1st MAR.

Fig AII-23. 1st MARDIV VHF multichannel assignment plan.

OBTAINING ECAC SUPPORT

Requests for support should be directed to:

Marine Corps Deputy Director (CM)
ECAC, North Severn
Annapolis, Maryland 21402
AUTOVON: 281-2555
Commercial: (301) 267-2555

Messages should be sent via AUTODIN to "ECAC ANNAPOLIS MD/ /CM/ /." To expedite ECAC support, requests for support from the field can be made by telephone to either the Marine Corps Deputy Director or the Operational Support Team (AUTOVON 281-2452), if unclassified. The date by which the material is needed should also be included.

ANALYSIS RESULTS

Results of analyses may be transmitted in various ways. The method that provides the fastest response is to send results via teletype (AUTODIN). The following types of analyses can be transmitted via AUTODIN:

(1) 4/3 Earth Terrain Profile.

(2) HF Sky wave Propagation Charts.

(3) HF Ground wave Propagation Charts.

(4) Microwave Reliability Predictions.

(5) Frequency Analysis.

Unclassified results may also be transmitted via telecopier. If it is required that the results be sent via telecopier, the name of the point of contact and the commercial and AUTOVON number should be provided. If analysis results must be mailed, the requesting command should allow 5-7 days for delivery. Analysis results will always be sent via AUTODIN wherever possible.

FUNDING

Operational support provided to requesting commands can fall into two general categories, classified by ECAC as nonrecurring and recurring efforts. Nonrecurring efforts that take the form of consultative or short-term analyses requiring one man-week or less will be provided at no cost to the Marine Corps, subject to the approval of the Director, ECAC. Funding will be required from the operational command for efforts for which the estimated manpower exceeds one week.

Questions regarding funding should be addressed to the Marine Corps Deputy Director, Electromagnetic Compatibility Analysis Center (ECAC) Capabilities and Services.

☆U.S. GOVERNMENT PRINTING OFFICE: 1985 461 543 10071

TAE-1

STUDENT COURSE CONTENT ASSISTANCE REQUEST

DATE:

COURSE NUMBER
COURSE TITLE

NAME
RANK
MOS

SOCIAL SECURITY NUMBER

1. Use this form for any questions you may have about the course. Write out your question and refer to the study unit, work unit, or study question with which you are having problems. Complete the self-addressed block on the reverse side. Before mailing, fold the form and staple it so that MCI's address is showing. Additional sheets may be attached to this side of the form.

MY QUESTION IS:

OUR ANSWER IS:

SIGNATURE (TITLE OR RANK)

STUDENT: Detach and retain this portion.

DATA REQUIRED BY THE PRIVACY ACT OF 1974
(5 U.S.C. 522A)

1. AUTHORITY: Title 5, USC, Sec. 301. Use of your Social Security Number is authorized by Executive Order 9397 of 22 Nov 43.

2. PRINCIPAL PURPOSE: The Student Course Content Assistance Request is used to transmit information concerning student participation in MCI courses.

3. ROUTINE USE: This information is used by MCI personnel to research student inquiries. In some cases information contained therein is used to update correspondence courses and individual student records maintained by the Marine Corps Institute.

4. MANDATORY OR VOLUNTARY DISCLOSURE AND EFFECT ON INDIVIDUAL NOT PROVIDING INFORMATION: Disclosure is voluntary. Failure to provide information may result in the provision of incomplete service to your inquiry. Failure to provide your Social Security Number will delay the processing of your assistance request.

INSTRUCTIONS TO STUDENT

1. Fold so that MCI address is outside
2. Insert course number in square marked "Course Number" below
3. Seal with scotch tape or one staple
4. Mail to MCI

BUSINESS REPLY MAIL

FIRST CLASS PERMIT NO. [illegible] WASHINGTON D. C.

POSTAGE WILL BE PAID BY U.S. MARINE CORPS

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

UNITED STATES MARINE CORPS
MARINE CORPS INSTITUTE
P. O. BOX 1775
ARLINGTON, VA 22223

STUDENT REQUEST/INQUIRY
MCI - R14 K

DATE SENT: ____________
DATE RECEIVED AT MCI: ____________

COURSE NUMBER	COURSE TITLE

COMPLETE ALL PORTIONS OF SECTION I

Section 1. Student Identification

Rank	Initials	Last Name	MOS

SSN ☐☐☐—☐☐—☐☐☐☐

REPORTING UNIT CODE (RUC)

MILITARY ADDRESS
____
____
ZIP CODE

INSTRUCTIONS: Print or type name, rank, and address clearly. Include ZIP CODE. Only Class III Reservists may use civilian address.

Section 2. CHECK THE APPROPRIATE BOX AND FILL IN THE APPROPRIATE SPACES.

FOR REGULAR AND CLASS II RESERVE MARINES THIS FORM MUST BE SIGNED BY THE COMMANDING OFFICER OR HIS REPRESENTATIVE, i.e. TRAINING NCO.

1. ☐ EXTENSION - Please grant an extension. (Will not be granted if already on extension.)
2. ☐ NOTICE OF COURSE COMPLETION - Final Exam Sent On____________. (New exam will be sent if exam not received at MCI.)
3. ☐ REENROLLMENT - Student has course materials (See para. 4003 of Vol. I of MCI Catalog for information on reenrollment.)
4. ☐ OVERDUE FINAL EXAM - Last (Review) lesson sent on ____________. Please send exam.
5. ☐ Please send new ANSWER SHEETS.
6. ☐ Please send missing course materials (Not included in course package.) Lessons_____ Manual______ Other____________
7. ☐ CHANGE - Rank________ Name____________ Social Security Number ☐☐☐-☐☐-☐☐☐☐ RUC ____________
8. ☐ OTHER (explain)____________________
____

FOR MCI USE ONLY

1. D____
2. On SMF____ K____ L ____
3. C____
4. L____
5. Q____
6. P____
7. E____
8. ____________________
____
____

DATE COMPLETED____________________

ORIGINATOR CODE____________________

Note: This form will not be returned by MCI. If request is valid, transaction will show on next UAR or on MCI-R1_ form.

____
SIGNATURE-TITLE OR RANK
(MUST BE CO OR REPRESENTATIVE)

STUDENT: Detach and retain this portion.

DATA REQUIRED BY THE PRIVACY ACT OF 1974
(5 U.S.C. 522A)

1. AUTHORITY: Title 5, USC, Sec. 301. Use of your Social Security Number is authorized by Executive Order 9397 of 22 Nov 43.

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